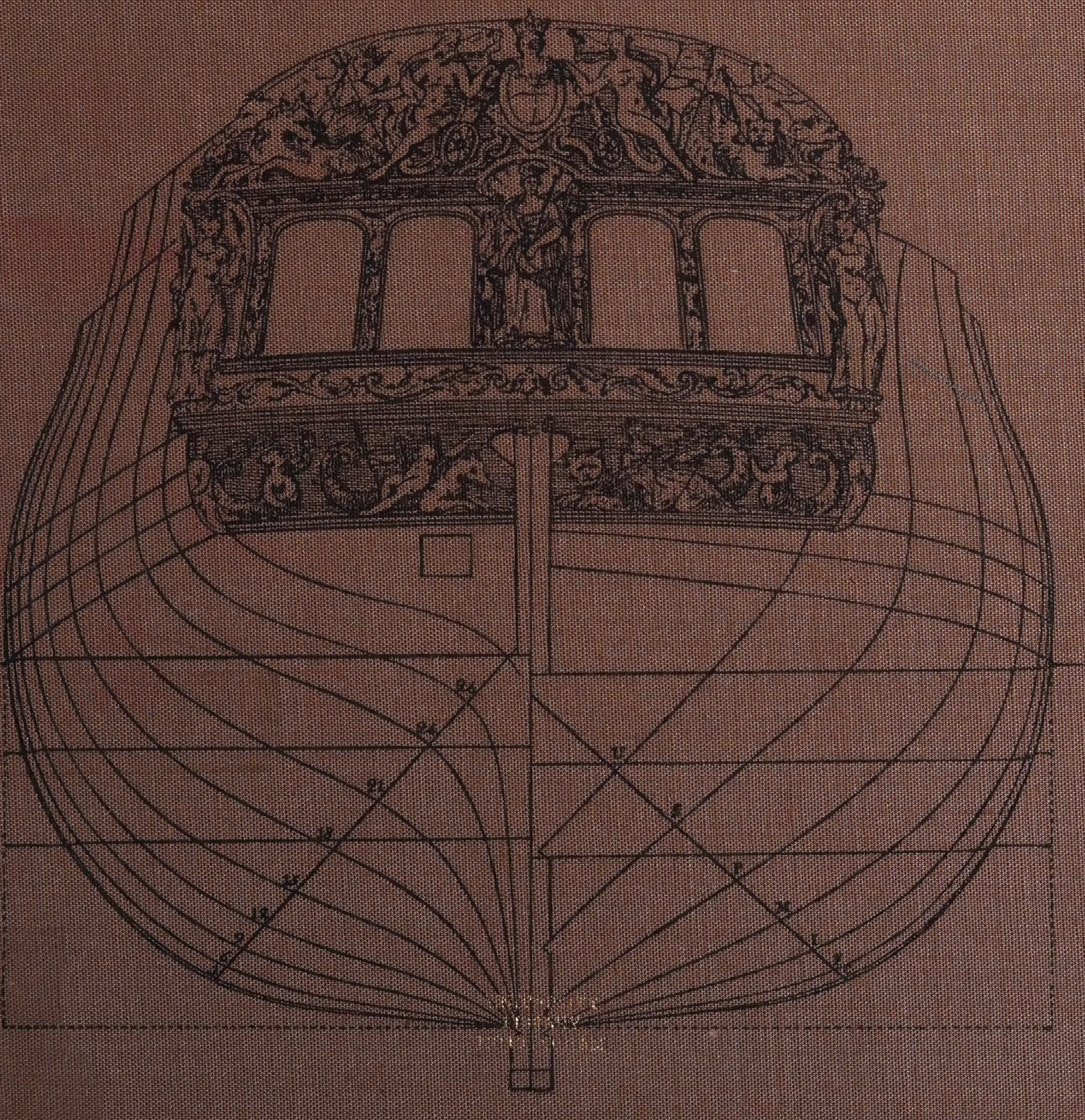
ARCHITECTURA NAVALIS MERCATORIA

CHAPMAN



Chapman · Architectura Navalis Mercatoria

Author's Preface to the
»Tractat om Skepps-Byggeriet« 1775
On the resistance which a ship in motion meets
from the water
On the dimensions of ships
On the proportions of privateers
On the proportions of masts and yards
for merchant ships
On the construction of the scale of solidity
On the measurement for tonnage and stowage
On the accommodations for provisions

Fredrik Henrik af Chapman

ARCHITECTURA NAVALIS MERCATORIA

Adlard Coles Ltd London

Introduction

Architectura Navalis Mercatoria by Fredrik Henrik af Chapman was first published in Stockholm 200 years ago, in 1768. The present, bicentenary edition of the famous work is dedicated to the memory of this great pioneer of naval architecture, who did so much to turn shipbuilding into a science. Proof of the signal importance of Chapman's work is rendered not least by the fact that his *Architectura* ran into many editions and, above all, that the *Tractat om Skepps-Byggeriet (Treatise on Shipbuilding)*, completed several years later, has been translated into many languages.
The *Tractat* was translated into French in 1779 by Lemonnier, in 1781 by Vial du Chairbois. In 1813 it was translated into English by Rev. James Inman, early in the 19th century into Russian, and in 1864 into German by Prömmel.
This *Tractat* is far more than a mere explanatory text to go with the plans contained in *Architectura Navalis Mercatoria*, as Chapman had originally intended. It is virtually a manual of design of various types of craft of that period. For this reason the editor and publishers of this edition have thought it logical to combine the two parts, introducing in this way the author's own comments.
Thus, selected parts of the 19th-century translation by the Rev. James Inman of the *Tractat om Skepps-Byggeriet* have been extracted, while the data such as dimensions, armament, cost etc. of individual ships featured in *Architectura Navalis Mercatoria* have been grouped for each plate and printed alongside it.
Linear measures have always been quoted in Swedish feet (1 ft = 0.296 m), carrying capacity in heavy lasts (1 Swedish heavy last = 2.4 long tons = 2.48 French tonneaux).
The editor and publishers hope that this mid-18th century collection of ships' plans and contemporary text by the great naval architect Fredrik Henrik af Chapman will give pleasure to all interested in the history of naval architecture, to all those fascinated by the influence of science on the arts of past ages, to many model builders and others interested in shipbuilding.

Fredrik Henrik Chapman was born on September 9, 1721 in Gothenburg in Sweden. His father, Thomas Chapman, who had emigrated from Yorkshire, then held the rank of *holmmajoren* at the Gothenburg Naval Dockyard, after having been enlisted into the Swedish Navy as *capitaine* in 1716 by Charles XII.
It is not surprising that the boy was attracted to his father's occupation and in 1738 joined the Naval Dockyard as a shipbuilding apprentice. After the completion of his apprenticeship he worked at various Swedish shipyards to broaden his knowledge. Quite early in his career he took an interest in drawing ships' plans.
From 1741 to 1743 Chapman worked as a ship's carpenter in London. His curiosity and his frequent visits to shipyards, during which he assiduously observed and made notes on British shipbuilding, were naturally met with suspicion, and once he was even arrested for suspected espionage. He was soon released, however, and given the opportunity to serve in the British Navy. But he refused the offer and returned to Sweden in 1744.
In partnership with the merchant Bagge, Chapman took over a Gothenburg shipyard which specialized in repairing ships of the East India Company. But he soon realized that the whole of shipbuilding, as it was practised in those days, was incapable of any real increase in efficiency, simply because it lacked a scientific basis and systematic working methods. He dissolved his partnership with Bagge in 1749 and spent his time studying, especially mathematics. He studied in Stockholm under Frederik Palmquist and in 1750 in London under Thomas Simpson, founder of a method of calculating the sectional areas of a hull published as Simpson's Rule in 1743 and still in use by shipbuilders today. In England Chapman also acquainted himself with the art of copper etching.
During the following years he travelled in Holland and France, where he visited shipyards, especially the ones at Brest and Toulon. Not only did he get to know many different types of ships, he also made a thorough study of the various building and finishing methods. After another visit to England he finally returned to his native Sweden in 1757.
Chapman's reputation had gone before him. He was appointed Deputy Master Shipbuilder to the Navy and in 1760 was called to Sveaborg as Master Shipbuilder by Major General Ehrensvärd. There he was to use his own ideas in designing craft suitable to defend the Finnish coast as part of the so-called 'skerry fleet'. The prevalent conditions among the Finnish skerries—i. e. unfavourable winds and shallow water—gave rise to the emergence of the so-called skerry frigates, a type of craft similar to the galleys, propelled by sails and oars. But in action two other types designed by Chapman, the 'armed sloop' and the 'armed yawl', proved more successful.
In 1764 Fredrik Henrik Chapman became Chief Shipbuilder to the Swedish Navy at Karlskrona and Stockholm, succeeding Sheldon and Sohlberg. In Stockholm he was made a member of a commission which was working out

a classification of types of warships, with the object of standardizing types according to their uses and at the same time standardizing the stocks of parts and materials kept at shipyards. The work of this commission was not finished until 1768.

In 1765 Chapman started work on his *Architectura Navalis Mercatoria*, while his nephew, Lars Gobman, made the copper engravings of the drawings. However, the finished work was not published until 1768. Its modest title hardly does justice to the actual contents of the book. Based on Chapman's very extensive and systematic collection of types of ships from different countries (with Swedish craft being understandably in the majority), it features not only merchant ships, as the title suggests, but also includes a considerable number of warships of various types.

The outstanding thing about Chapman's book by comparison with previously published works of a similar nature is the systematic classification of ships into types—the connection between this and Chapman's work on the above-mentioned commission is obvious—and the presentation of his own, as well as his contemporaries', scientific findings on questions such as the position of the center of gravity and the metacenter for different states of trim.

Apart from a table giving the principal dimensions of ships, the book contained no explanatory text whatever. Chapman had planned a separate volume of text and calculations, which he intended to have published in the following year. But the *Tractat om Skepps-Byggeriet* did not appear till 1775. By that time it was more than a mere explanatory volume to go with the purely pictorial *Architectura Navalis Mercatoria;* it was chiefly a handbook on the design of ships.

It deals in great detail with displacement, location of the center of gravity and metacenter, stability, resistance, shape and dimensions of ships, measurement for tonnage, etc.

In recognition of his contributions to shipbuilding, Chapman was knighted in 1772. Early in the reign of Gustav II he became a member of a commission which was to work out proposals for the structure and organisation of the Navy. Between 1774 and 1778 the *Konung Adolf Fredrik*, the 62-gun ship *Prins Fredrik Adolf* (1774) and the 60-gun ship *Vasa* (1778) were built to Chapman's plans. In 1776 he obtained the rank of Colonel in the Swedish Navy and member of the Admiralty Board. To prove the seaworthiness and efficiency of Chapman's light construction as compared to Sheldon's heavy ships a trial sail was arranged in 1779 between the *Prins Fredrik Adolf* and Sheldon's ship *Drottning Sofia Magdalena* built in 1768. The outcome was inconclusive, which is why, in 1780, an examining commission was appointed under the chairmanship of Major General of the Fleet Henrik af Trolle. Its task, until 1785, was to work out plans for the whole of the shipbuilding at Karlskrona Naval Dockyard. In this work Chapman took an important part.

In 1781 Chapman was appointed *Arbetsdirektör* (works manager) and as such was in charge of the shipbuilding side at the Karlskrona Naval Dockyard. One year later, after the resignation of the 'Admiral of the Yard', Carl Tersmeden, he was put in charge of the entire yard, which also made him responsible for the departments of rigging and artillery.

Proof of the validity and importance of Chapman's work in the field of rationalisation is furnished by a report, dated November 7, 1782, by the Admiral and Commander in Chief of the Fleet, Henrik af Trolle, to the King:

> 'Yesterday morning, at 8 o'clock, the 60-gun ship *Kronprins Gustav Adolf* and the frigate *Bellona* with 40 guns were launched after having been finished in 4 months. On the same day, at 1 o'clock in the afternoon, the keels were laid and stern and stem posts erected of the 60-gun ship *Fäderneslandet* and of the 40-gun frigate *Minerva*. All ribs and other timber for these vessels were also sawn and bent within 4 months. These are occurrences, quite apart from the fact that costs are now much lower than ever before, which have never before happened at Your Royal Majesty's Dockyard.'

The superiority of Chapman's designs and construction over Sheldon's was clearly proved 5 years later when the *Kronprins Gustav Adolf* and Sheldon's *Drottning Sofia Magdalena* sailed together on a cruise from Karlskrona into the North Sea and the former sailed with her gun ports open, while the latter had to close hers.

Between 1782 and 1785 the following ships, built to Chapman's designs, were launched and commissioned:

60-gun ships:		40-gun frigates:	
	Kronprins Gustav Adolf		*Bellona*
	Fäderneslandet		*Minerva*
	Ömheten		*Venus*
	Rättvisan		*Diana*
	Dygden		*Fröja*
	Äran		*Thetis*
	Försigtigheten		*Camilla*
	Dristigheten		*Galathea*
	Manligheten		*Eurydice*
	Tapperheten		*Zemire*

In 1783 Fredrik Henrik af Chapman was promoted to *Varvsadmiral* and Rear Admiral, in 1791 to Vice Admiral. Between 1788 and 1790 war-time events showed that the big, three-decked Russian ships were very well capable of manoeuvring among the Finnish skerries. This caused Chapman to draw up plans for a number of 'heavy' ships. In quick succession he submitted the designs for 66-, 74-, 80-, 94-, and 110-gun ships, which were approved but never built, because of financial considerations.

Only the 76-gun ship *Konung Gustav IV Adolf*, a ship of very much bigger dimensions than was usual in those days, was built in 1799. Her armament consisted of thirty 36-pounders, thirty 24-pounders and sixteen 12-pounders, and she had a displacement of 2700 tons. She was built according to the principles expounded by Chapman in his *Gründer till kännedom om linjeskepp* in 1795. In it, he lists the following 'necessary qualities of a *good* ship of the line':

1. Adequate stability against heeling. With all three topsails and topgallants, the spanker, fore topmast staysail and jib set a ship sailing 6 points off the wind must heel no more than 7°.
2. Good performance on all points of sailing.

The term 'ship of the line', of course, was not used by the Swedish Navy until 1808.

Besides these strictly practical and semi-theoretical activities, Chapman had for long occupied himself with experiments and theories to establish the form resistance of ships. More than 2000 model tests form the basis of his work *Fysiska rön om det motstånd kroppar lida, som föras rätt fram genom vattned*, published in 1795.

They also formed the basis of the so-called 'relaxation method' of developing the after lines of a ship, which was, however, abandoned by Chapman himself in favour of the older 'parabola method', after trial sails in the 40-gun frigate *af Chapman*. He still sailed this frigate himself at the age of 82!

In 1793 Chapman tendered his resignation, which was accepted. But his experience and knowledge continued to be drawn upon for the design and construction of new ships.

Fredrik Henrik af Chapman died in Karlskrona on August 19, 1808 at the age of 87, and so the life of one of the greatest shipbuilders of all times came to an end.

The qualities which set him apart from all others were his energy, his inexhaustible capacity for work combined with expert knowledge and experience, and the discipline with which he thought and acted.

In *Architectura Navalis Mercatoria* and *Tractat om Skepps-Biggeriet*, which have been combined in this edition, af Chapman has set himself a memorial which ensures that he and his work will not be forgotten in our times.

Bibliography:

Svenskt biografiskt handlexikon, Stockholm 1906.

E. Hägg: *Under tretungad flagga*, Stockholm 1941.

F. Neumeyer: Wissenschaftliche Einführung zum Werke des Admirals F. H. af Chapman' in: *Architectura Navalis Mercatoria*, Rostock 1962.

G. Timmermann: 'Schiffstheorie im 17. und 18. Jahrhundert', *Schiff und Hafen*, 14. Jahrgang 1962, Heft 6, pages 555 and 556.

Index and descriptions of the draughts contained in this work

Merchant ships or vessels

First class			
Plate I	1	Frigate built	Ship's rigging
II	2	Frigate built	Ship's rigging
III	3	Frigate built	Ship's rigging
IV	4	Frigate built	Ship's rigging
V	5	Frigate built	Ship's rigging
V	6	Frigate built	Ship's rigging
VI	7	Frigate built	Ship's rigging
VI	8	Frigate built	Snow rigging
VII	9	Frigate built	Schooner rigging
VII	10	Frigate built	Sloop rigging
Second class			
Plate VIII	11	Hagboat	Ship's rigging
IX	12	Hagboat	Ship's rigging
X	13	Hagboat	Ship's rigging
XI	14	Hagboat	Ship's rigging
Third class			
Plate XII	15	Pink	Ship's rigging
XII	16	Pink	Ship's rigging
XIII	17	Pink	Snow rigging
XIII	18	Pink	Brig rigging
XIV	19	Pink	Brig rigging
XIV	20	Pink	Sloop rigging
Fourth class			
Plate XV	21	Cat	Ship's rigging
XVI	22	Cat	Ship's rigging
XVII	23	Cat	Ship's rigging
XVIII	24	Cat	Ship's rigging
XVIII	25	Cat	Ship's rigging
XIX	26	Cat	Ship's rigging
XIX	27	Cat	Snow rigging
XX	28	Cat	Brig rigging
XX	29	Cat	Sloop rigging
XX	30	Cat	Sloop rigging
Fifth class			
Plate XXI	31	Bark	Ship's rigging
XXII	32	Bark	Ship's rigging
XXIII	33	Bark	Ship's rigging
XXIV	34	Bark	Ship's rigging
XXIV	35	Bark	Ship's rigging
XXV	36	Bark	Snow rigging
XXV	37	Bark	Brig rigging
XXVI	38	Bark	Brig rigging
XXVI	39	Bark	Sloop rigging
XXVI	40	Bark	Sloop rigging
Vessels, small draught of water			
Plate XXVII	1	Fly-boat	Ship's rigging
XXVIII	2	Bark	Ship's rigging
XXVIII	3	Bark	Snow rigging
XXVII	4	Bark	Schooner rigging
XIV	5	Bark	Galeass rigging
VII	6	Bark	Sloop rigging
XXIX	7	Bark	Brig rigging
XXIX	8	Bark	Kray rigging
XXIX	9	Bark	Sloop rigging
XXIX	10	Bark	Sloop rigging
XXX	11	Pink	Ketch rigging
XXX	12	Hoy	Tjalk rigging
XXX	13	Bark	Galeass rigging
XXVIII	14	Bark	Galeass rigging
XXX	15	Lighter	
XXX	16	Ferry boat	

Vessels for swift sailing and rowing

Packet boats		
Plate XLI	1	Frigate
XLI	2	Schooner
XLII	3	Sloop with two sorts of frames for more or less draught of water
XLII	4	Schooner
XLII	5	Sloop or Yacht
Pleasure vessels—for sailing		
Plate XLIII	1	Frigate
XLIII	2	Schooner
XLIV	3	Yacht
XLIV	4	Schooner
XLV	5	Yacht
XLV	6	Yacht
XLIV	7	Yacht
XLV	8	Yacht
XLV	9	Yacht
XLIV	10	Yacht
Pleasure vessels—for rowing		
Plate XLVI	1	A Row Galley
XLVI	2	A Barge
XLVII	3	A Barge
XLVII	4	A Barge
XLVII	5	A Barge
XLVII	6	A Barge
XLVII	7	Pinnace or Barge
XLVII	8	Yawl
Boats large and small for the use of ships		
Plate XIV	1	Launch
Plate XXVI	1	Pinnace

XLVIII	2	Launch	VII	2	Pinnace	XLVIII	10	Yawl	LIII	10	Boat for sailing on the ice
XLVIII	3	Launch	XIII	3	Pinnace	XLVIII	11	Yawl or Pram	LIII	11	Proportion of sails for the same
XXVI	4	Launch	XIII	4	Pinnace						
XLVIII	5	Longboat	XX	5	Yawl						
XLVIII	6	Longboat	XX	6	Yawl						
XLVIII	7	Longboat	XXV	7	Yawl						
XLVIII	8	Longboat	XXV	8	Yawl						
XLVIII	9	Longboat	XXV	9	Yawl						

Privateers

Plate XXXI	1	Frigate
XXXIII	2	Frigate
XXXIV	3	Frigate
XXXV	4	Frigate
XXXVI	5	Frigate
XXXVII	6	Frigate
XXXVIII	7	Frigate
XXXVIII	8	Snow
XXXIX	9	Ketch
XXXIX	10	Ketch
XL	11	Schooner
XL	12	Schooner
XL	13	Sloop
Plate XXXII:		Section & Contrivances of the Privateer No. 1

Several kinds of vessels used by different nations

Vessels of war

Plate LV	9	*La Sirenne* a French frigate
LV	10	*The Unicorn* an English frigate
LVI	11	*Jaramas* a Swedish frigate
LVI	12	*Blaa Hejren* a Danish frigate
LVII	14	*Neptunus* a privateer built at Ostende
LVII	15	A Bermuda sloop
LVII	16	A French tartane
LVIII	17	An Algerian xebec
LVIII	18	*La Capitana*, a rowing galley of Malta
XLIX	1	The yacht *Carolina* belonging to His Britannick Majesty
LX	6	An English cutter

Merchant ships or vessels

Plate LI	1	An English East Indiaman
LII	2	An English West India trader
LII	3	An English trader, river built
LIII	5	*Le Chameau* fly-boat, a French store ship
LIII	6	A Dutch fly-boat
LIV	7	A Dutch smack
LIV	8	A Dutch galiot or hoy with three masts
LX	7	A Dutch hoy with two masts
LX	8	A French felucca of 10 pairs of oars
LX	9	A scoote used by the Finlanders

Fishing vessels

Plate LIX	1	A Dutch dogger for carrying lobsters
LIX	2	An English herring buss
LIX	3	An English smack for flatfish
LX	4	A vessel with a well for carrying fish, used at Stockholm
LX	5	One d° less of the same kind

Different sorts of smaller vessels

Plate XLIX	2	An 8-oared barge, English
XLIX	3	A Dutch Heerenyacht
LII	4	A close lighter, English
XLIX	4	A Dutch Schuit or Boyer
L	5	A Swedish boyer or pleasure boat
L	6	A Norway yawl for sailing
L	7	A Spanish bark used in Cadiz
L	8	A Venetian gondola
L	9	An English ferry
L	10	A Greenland pinnace for whale fishing
L	11	An English hoy or lighter
L	12	A hopper for carrying of ballast
L	13	A chalk barge, an English vessel
XLI	14	A French pinnace of 6 oars
LVI	19	Galeass, a Baltick vessel

Plate LXI: Three different methods of launching ship: No. 1 the French, No. 2 the English and No. 3 the Dutch.

Plate LXII: Several figures representing the different manners of rigging which are most in use in the Northern Countries.

ARCHITECTURA NAV

NAVIUM varii generis *MERCATORIAR*
ALIARUMQUE, cujuscunqve conditionis v
exemplis æ
Demonſtrationibus denique, Dimenſionibu
Aut
FRIDERICO HEN

S:R:Majeſt: I
R: Acad: Scient:

HOLMIÆ Aº

ALIS MERCATORIA,

M, CAPULICARUM, CURSORIARUM,

molis, Formas et rationes exhibens:

incifis,

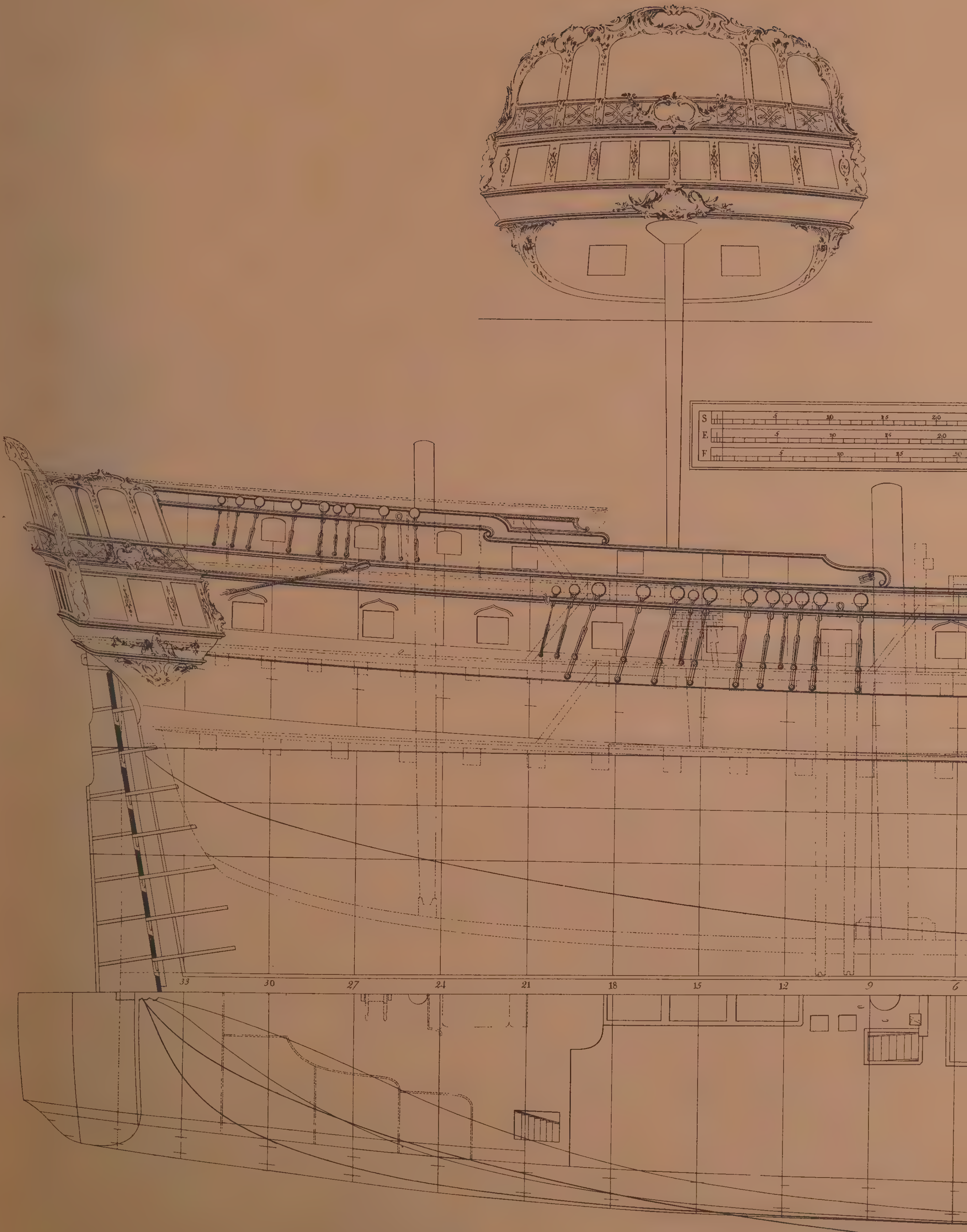
calculisque accuratisfimis illuftrata.

CHAPMAN.

ego,

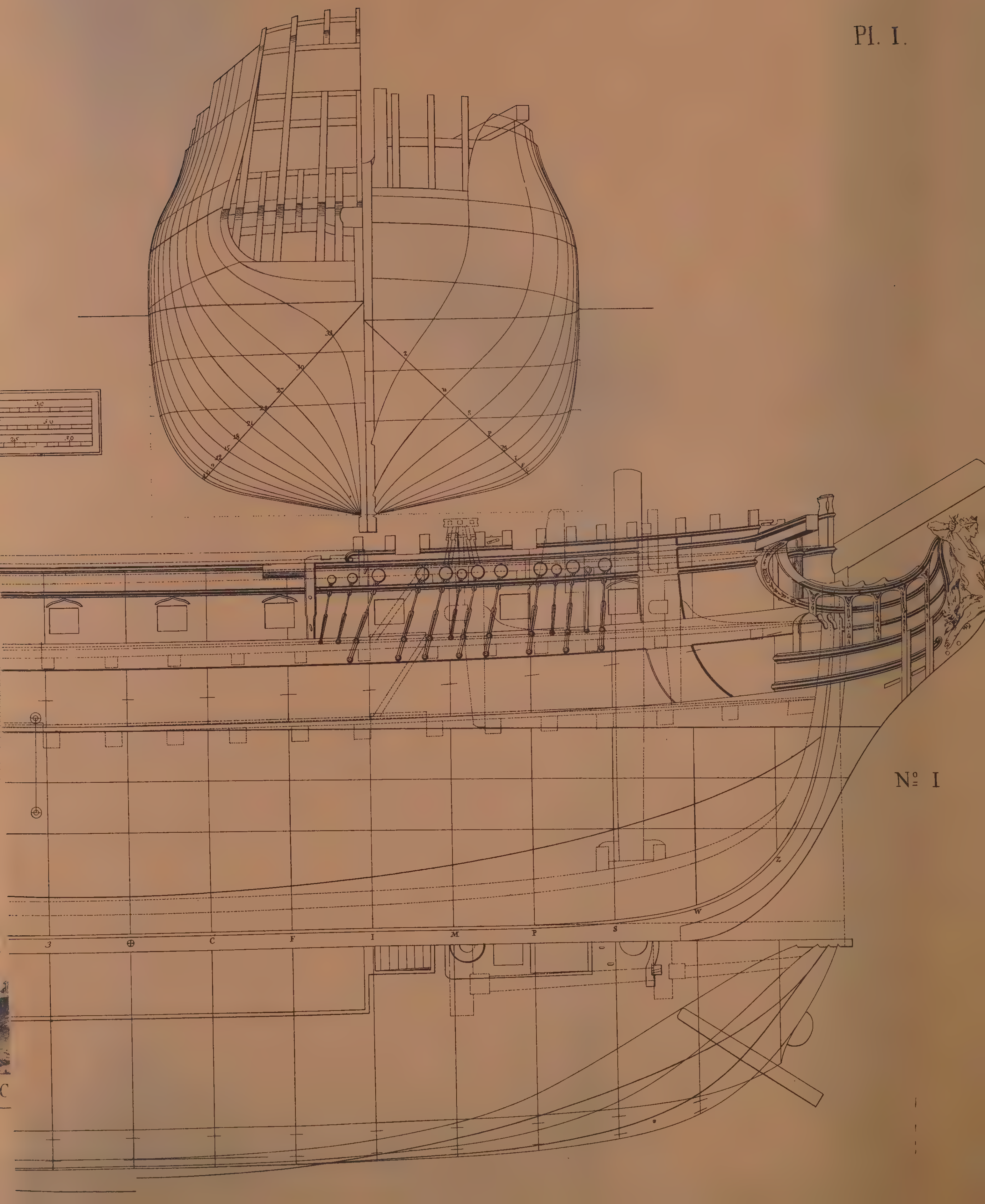
: Membro.

CCLXVIII.



S
E
F
33
30
27
24
21
18
15
12
9
6

Pl. I.



N° I

PLATE I

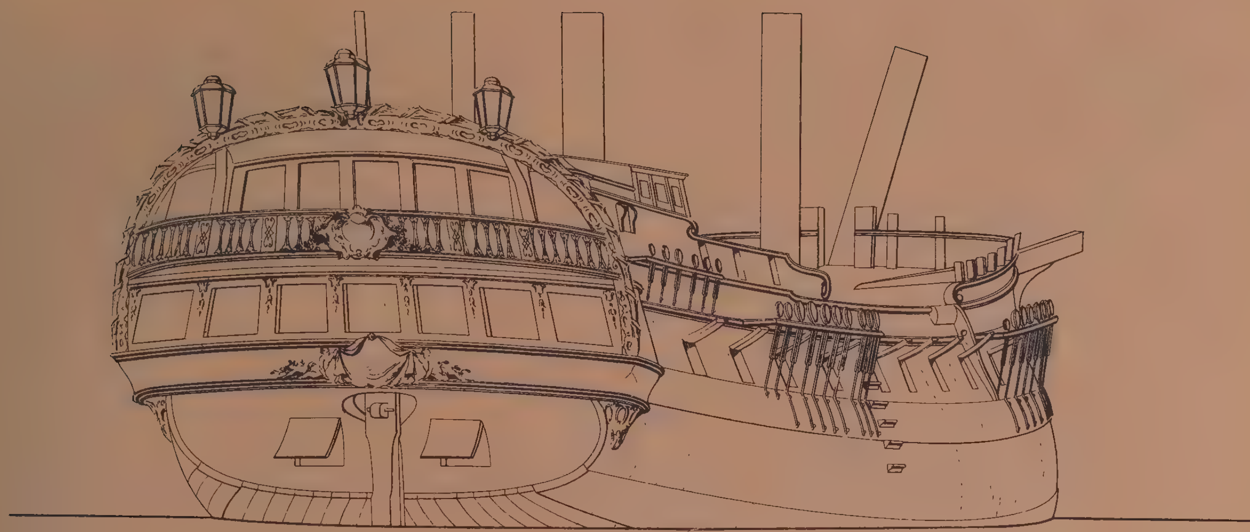
No 1 *Frigate (Merchant vessels, 1st class)*
with ship's rigging (See plate LXII, No 1)

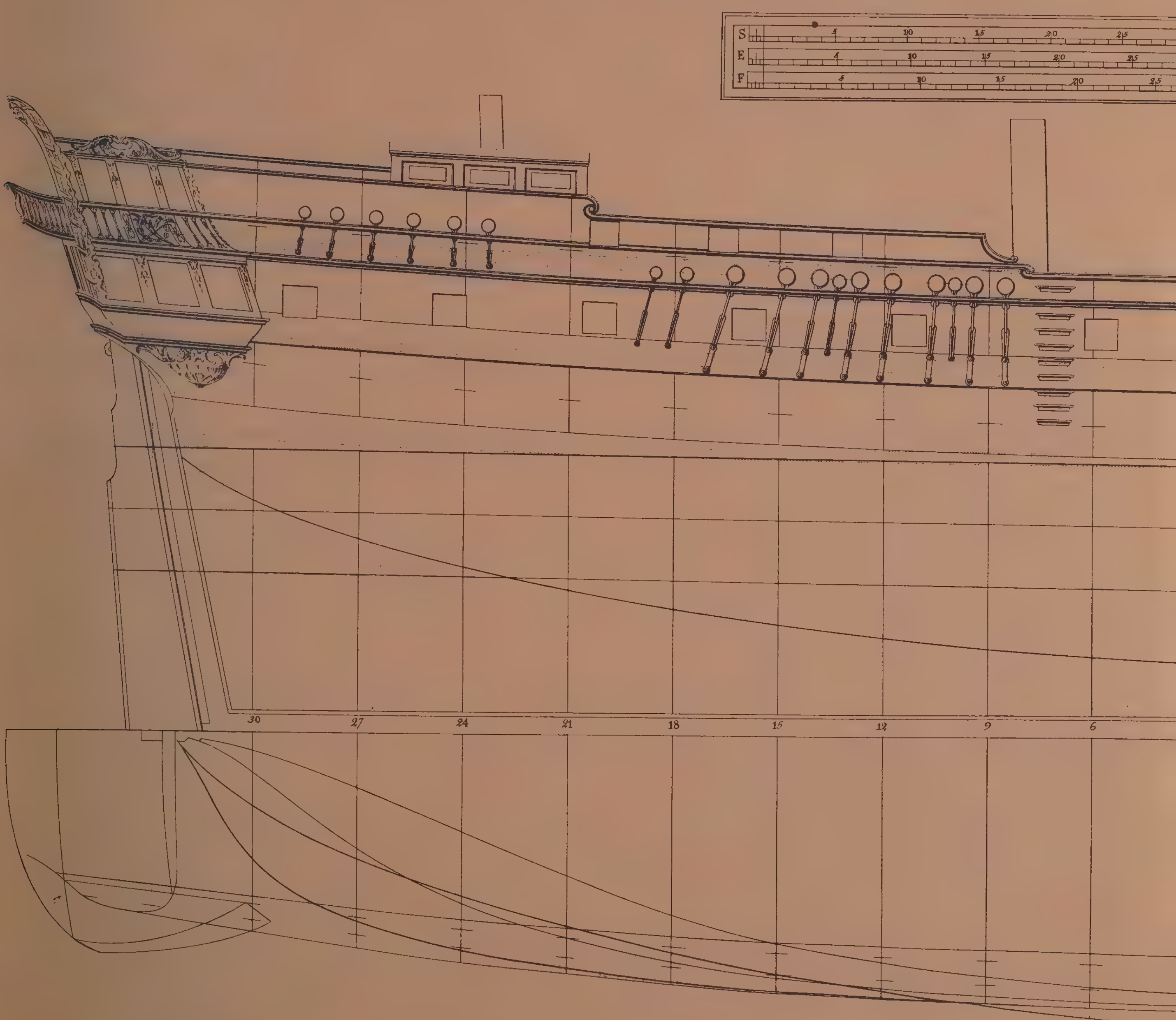
Length between perpendiculars	164ft
Breadth moulded	42 1/2ft
Draught as it is on the plan	22ft 8in
Draught laden	23ft 11in
Burthen	532 heavy lasts
Area of the midship frame	713 sq ft
Area of the load waterline	5691 sq ft
Displacement	78090 cu ft
Total cost of construction	100000 krone

PLATE II

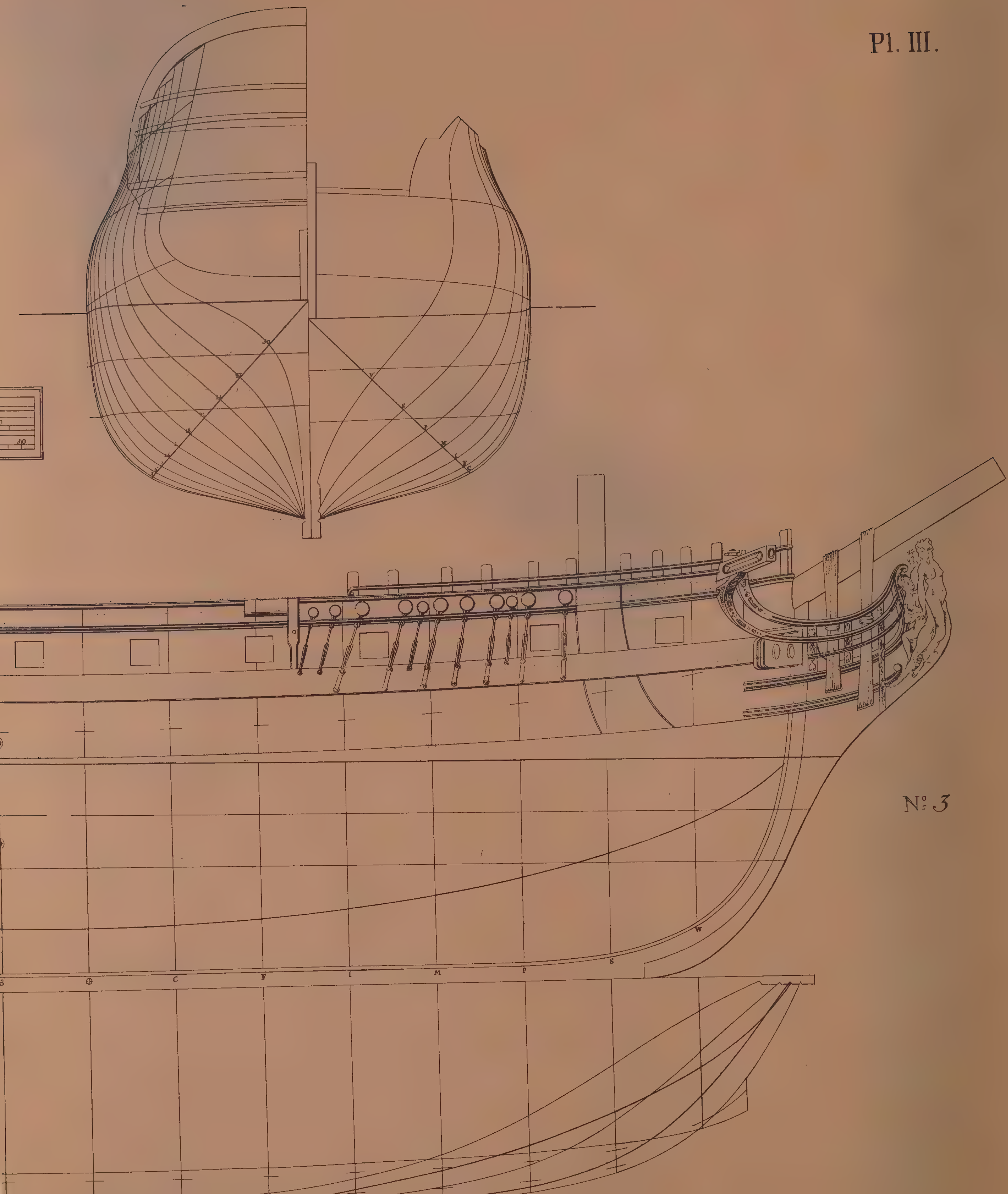
No 2 *Frigate (Merchant vessels, 1st class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	152 1/2ft
Breadth moulded	40ft
Draught as it is on the plan	21ft 3in
Draught laden	22ft 6in
Burthen	437 heavy lasts
Area of the midship frame	615 sq ft
Area of the load waterline	4959 sq ft
Displacement	62191 cu ft
Total cost of construction	77442 krone




S 5 10 15 20 25
E 5 10 15 20 25
F 5 10 15 20 25
30 27 24 21 18 15 12 9 6

Pl. III.



N°. 3

PLATE III

No 3 *Frigate (Merchant vessels, 1st class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	140ft
Breadth moulded	37ft
Draught as it is on the plan	19ft 6in
Draught laden	20ft 9in
Burthen	354 heavy lasts
Area of the midship frame	526 sqft
Area of the load waterline	4263 sqft
Displacement	49012 cuft
Total cost of construction	57451 krone

PLATE IV

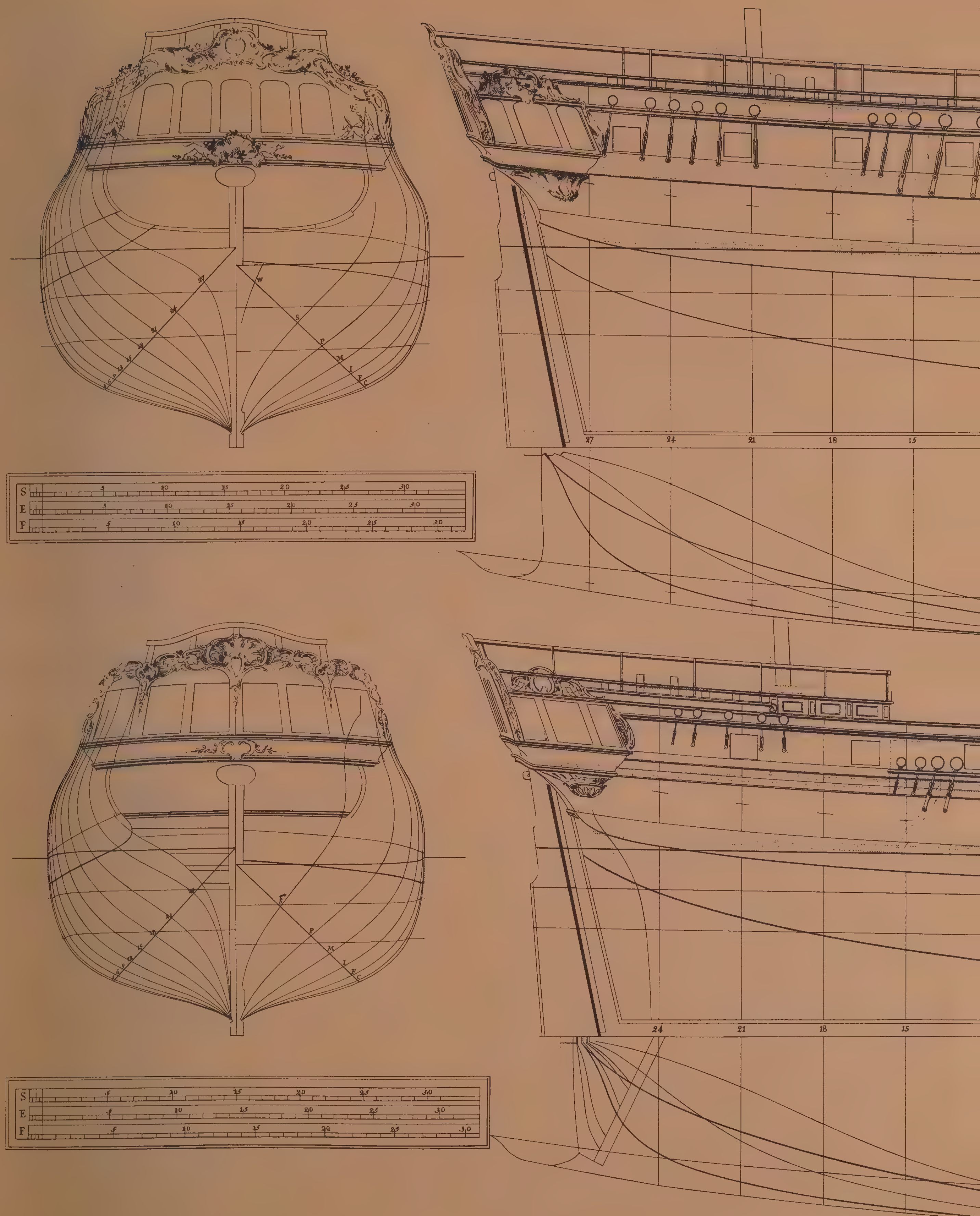
No 4	*Frigate (Merchant vessels, 1st class)*	
	with ship's rigging (see plate LXII, No 1)	
	Length between perpendiculars	128ft
	Breadth moulded	34 1/2ft
	Draught as it is on the plan	18ft
	Draught laden	19ft 3in
	Burthen	276 heavy lasts
	Area of the midship frame	438 sqft
	Area of the load waterline	3593 sqft
	Displacement	37282 cuft
	Total cost of construction	40597 krone

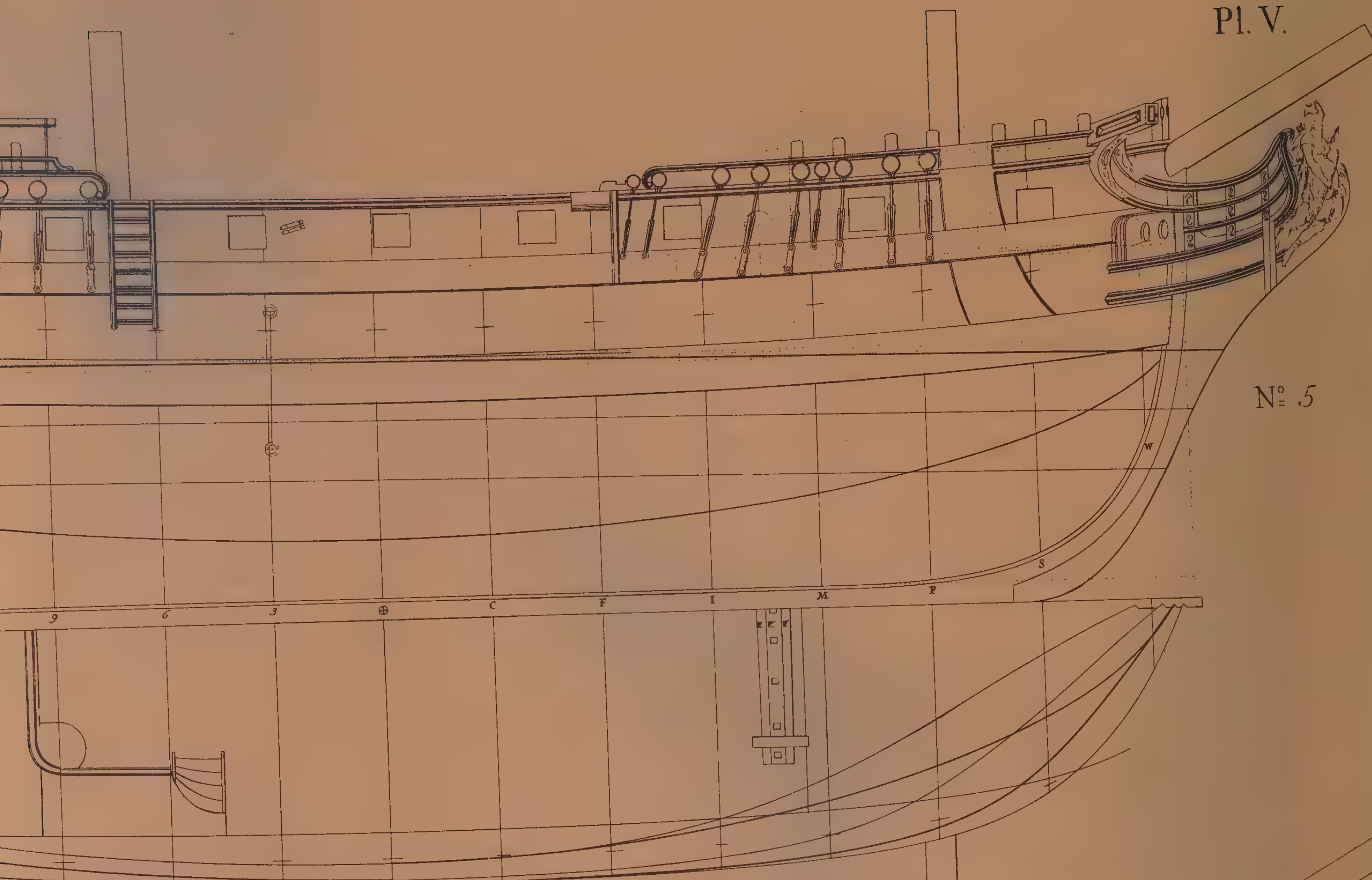
above right:

Scale of burthen for frigates

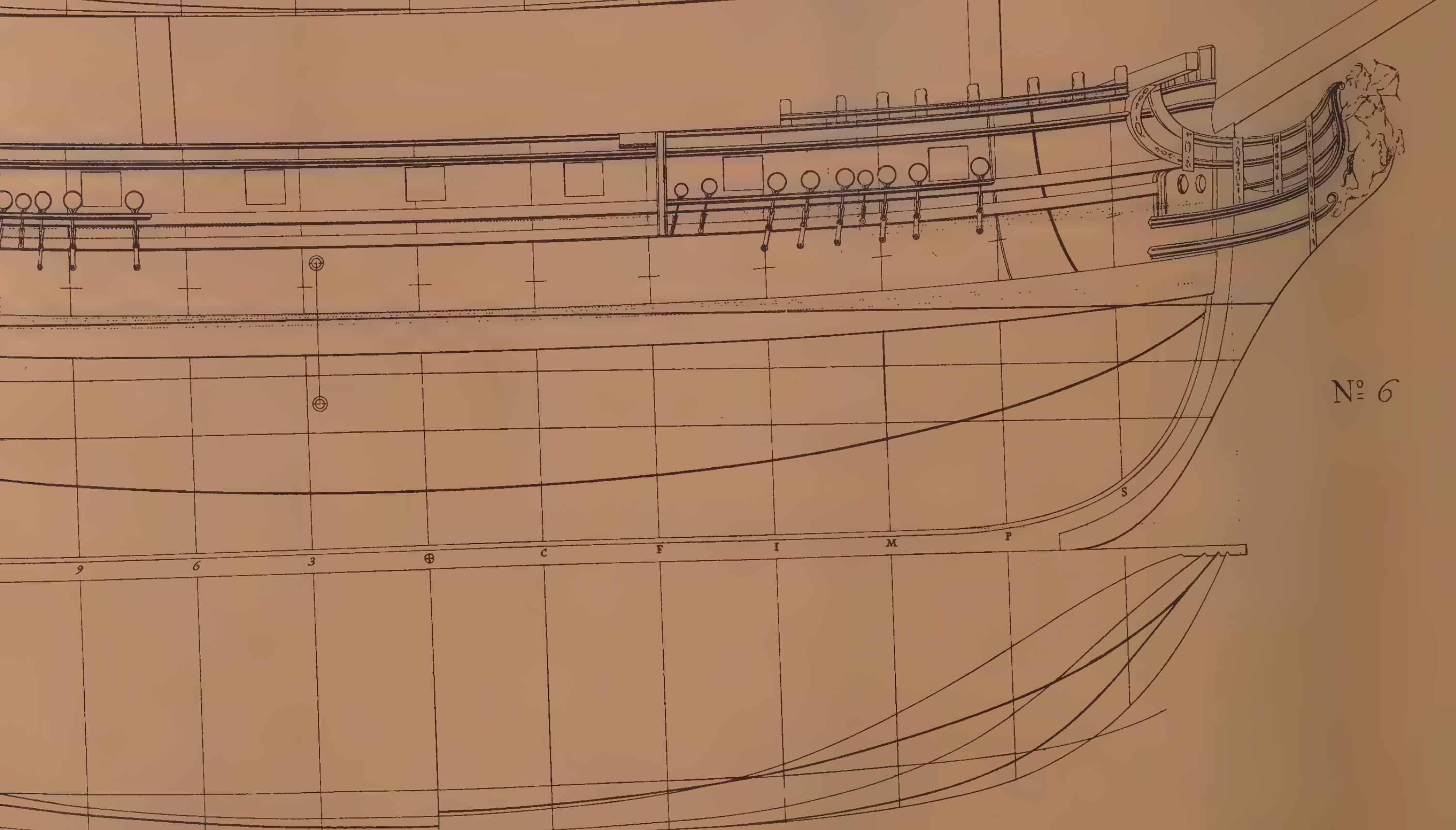
Plates I; II; III; IV; V,5; V,6; VI,7; VI,8; VII,9; and VII,10.

See page 99 for instructions on how to use the scale.


27 24 21 18 15
S 5 10 15 20 25 30
E 5 10 15 20 25 30
F 5 10 15 20 25 30
24 21 18 15
S 5 10 15 20 25 30
E 5 10 15 20 25 30
F 5 10 15 20 25 30



N° 5



N° 6

PLATE V

No 5 *Frigate (Merchant vessels, 1st class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	115 1/2ft
Breadth moulded	32ft
Draught as it is on the plan	16ft 6in
Draught laden	17ft 6in
Burthen	207 heavy lasts
Area of the midship frame	357 sqft
Area of the load waterline	3033 sqft
Displacement	27627 cuft
Total cost of construction	28614 krone

No 6 *Frigate (Merchant vessels, 1st class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	103 1/3ft
Breadth moulded	29 1/2ft
Draught as it is on the plan	14ft 6in
Draught laden	15ft 6in
Burthen	149 heavy lasts
Area of the midship frame	286 sqft
Area of the load waterline	2444 sqft
Displacement	19459 cuft
Total cost of construction	19486 krone

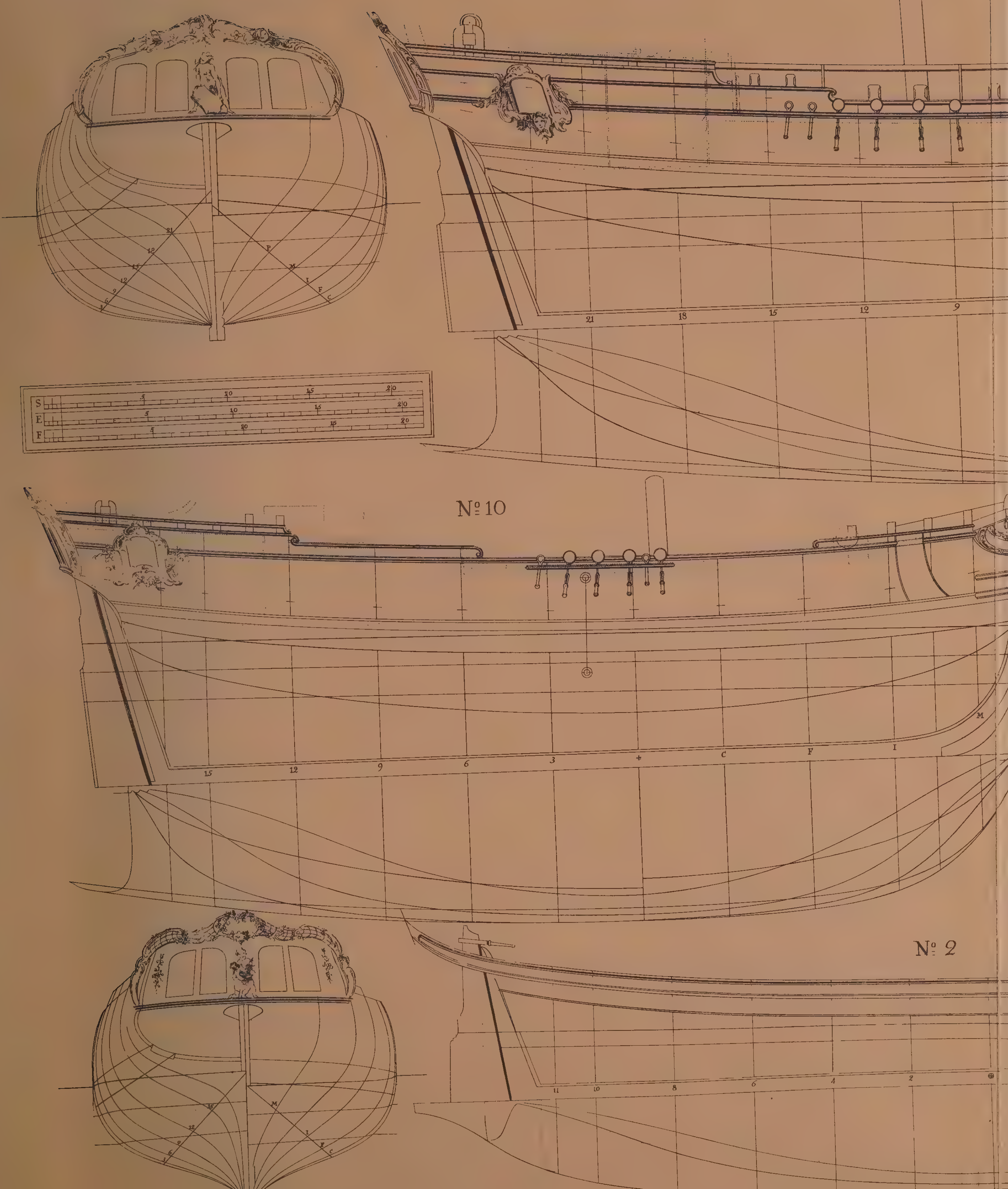
PLATE VI

No 7 *Frigate (Merchant vessels, 1st class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	921/4ft
Breadth moulded	262/3ft
Draught as it is on the plan	13ft 4in
Draught laden	14ft 1in
Burthen	105 heavy lasts
Area of the midship frame	229 sqft
Area of the load waterline	1965 sqft
Displacement	13862 cuft
Total cost of construction	12662 krone

No 8 *Frigate (Merchant vessels, 1st class)*
with snow rigging (see plate LXII, No 2)

Length between perpendiculars	80ft
Breadth moulded	231/2ft
Draught as it is on the plan	11ft 8in
Draught laden	12ft 5in
Burthen	71 heavy lasts
Area of the midship frame	173 sqft
Area of the load waterline	1515 sqft
Displacement	9042 cuft
Total cost of construction	7773 krone


Nº 10
Nº 2

Pl. VII.

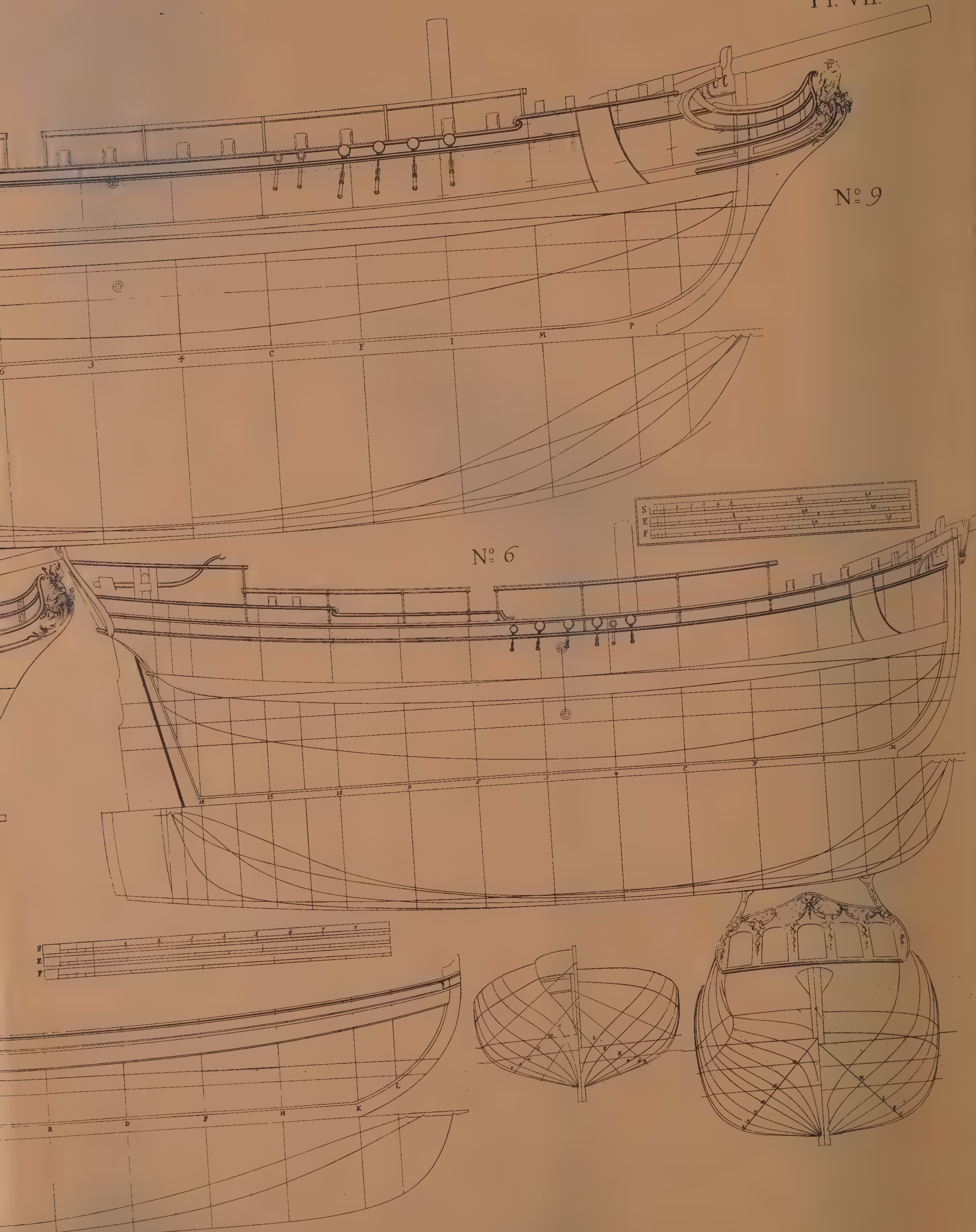


PLATE VII

No 9 *Frigate (Merchant vessels, 1st class)*
with schooner rigging (see plate LXII, No 6)

Length between perpendiculars	82ft
Breadth moulded	21 1/2ft
Draught as it is on the plan	8ft 4in
Draught laden	9ft 1in
Burthen	53 heavy lasts
Area of the midship frame	122 sq ft
Area of the load waterline	1333 sq ft
Displacement	6150 cu ft
Total cost of construction	5387 krone

No 10 *Frigate (Merchant vessels, 1st class)*
with sloop rigging (see plate LXII, No 12)

Length between perpendiculars	56ft
Breadth moulded	18 1/2ft
Draught as it is on the plan	8ft 7in
Draught laden	9ft 4in
Burthen	29 heavy lasts
Area of the midship frame	89 sq ft
Area of the load waterline	800 sq ft
Displacement	3173 cu ft
Total cost of construction	2619 krone

No 6 *Bark (Merchant vessels, small draught of water)*
with sloop rigging (see plate LXII, No 12)

Length between perpendiculars	60ft
Breadth moulded	18ft
Draught as it is on the plan	7ft 9in
Draught laden	8ft 3in
Burthen	40 heavy lasts
Area of the midship frame	108 sq ft
Area of the load waterline	891 sq ft
Displacement	4343 cu ft
Total cost of construction	2976 krone

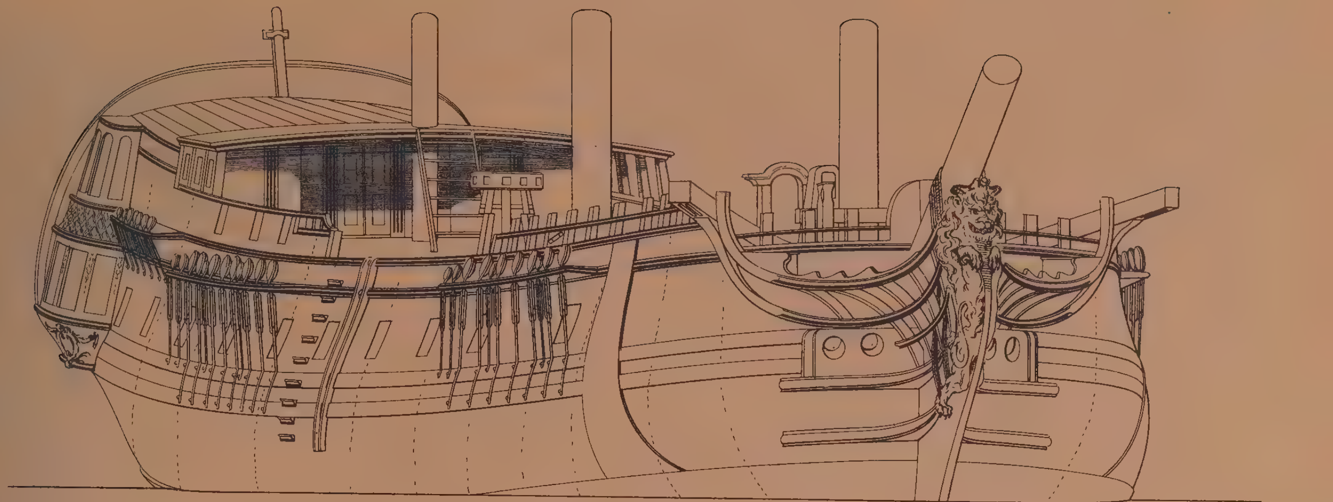
No 2 *Pinnace (Boats for the use of ships)*

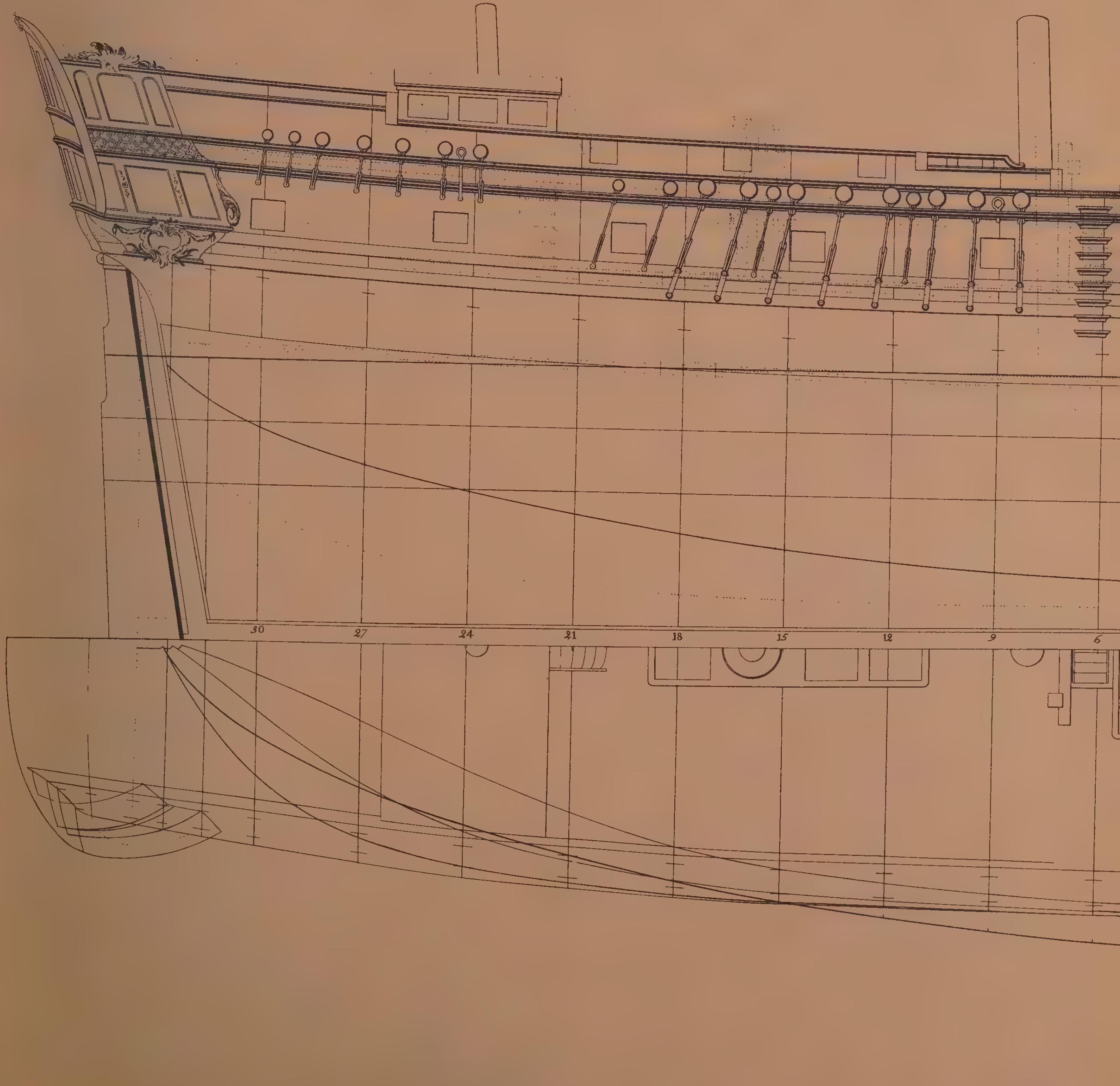
Length between perpendiculars	30 1/4ft
Breadth moulded	6 1/8ft
Pairs of oars	9

PLATE VIII

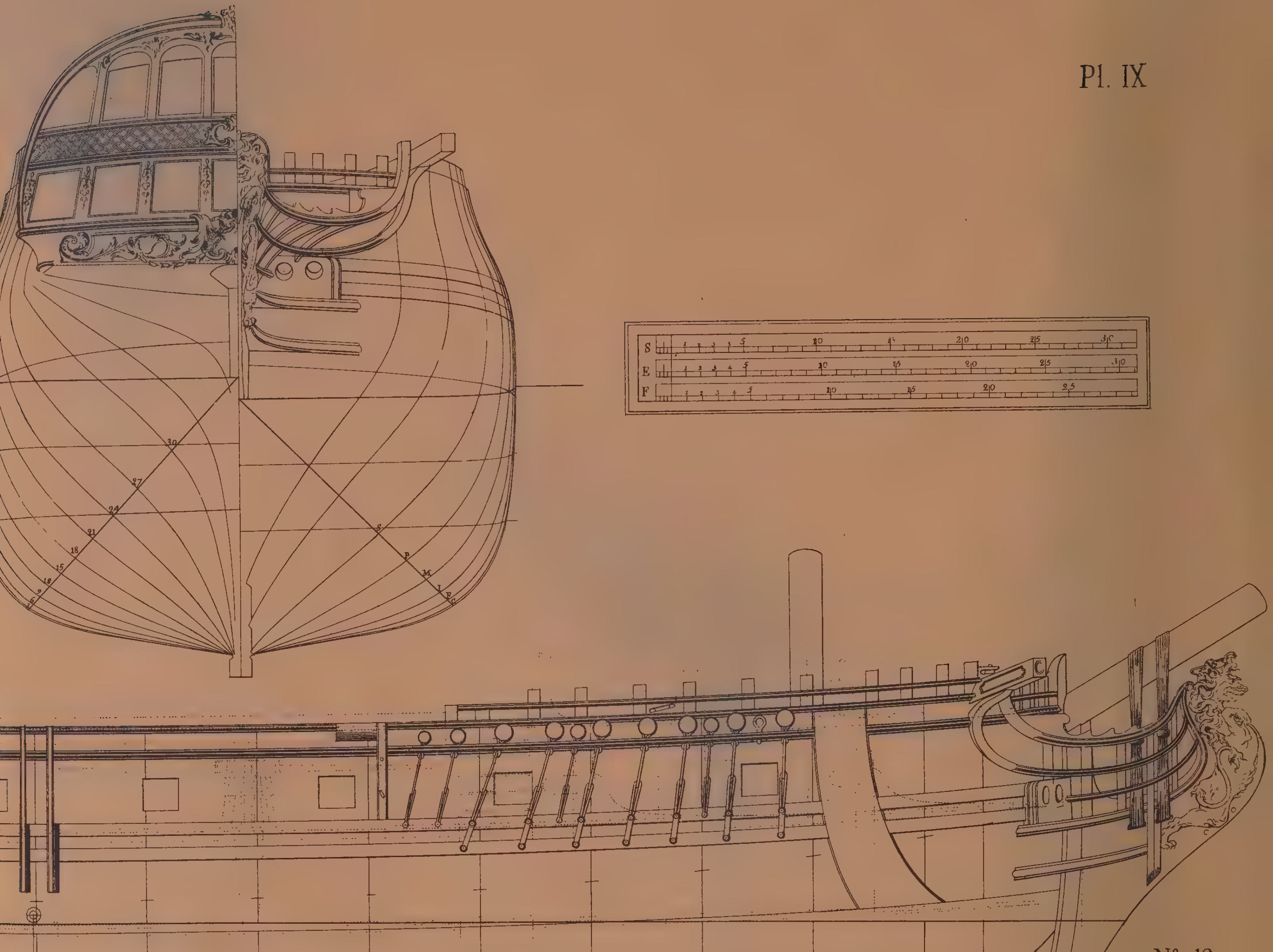
No 11 *Hagboat (Merchant vessels, 2nd class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	160 1/3ft
Breadth moulded	40ft
Draught as it is on the plan	21ft 9in
Burthen	483 heavy lasts
Area of the midship frame	676 sqft
Area of the load waterline	5510 sqft
Displacement	77216 cuft
Total cost of construction	88261 krone




30
27
24
21
18
15
12
9
6

Pl. IX



Nº 12

PLATE IX

No 12 *Hagboat (Merchant vessels, 2nd class)*

with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	148 3/4ft
Breadth moulded	37 5/6ft
Draught as it is on the plan	20ft 4in
Burthen	389 heavy lasts
Area of the midship frame	594 sq ft
Area of the load waterline	4727 sq ft
Displacement	61498 cu ft
Total cost of construction	70659 krone

above left:

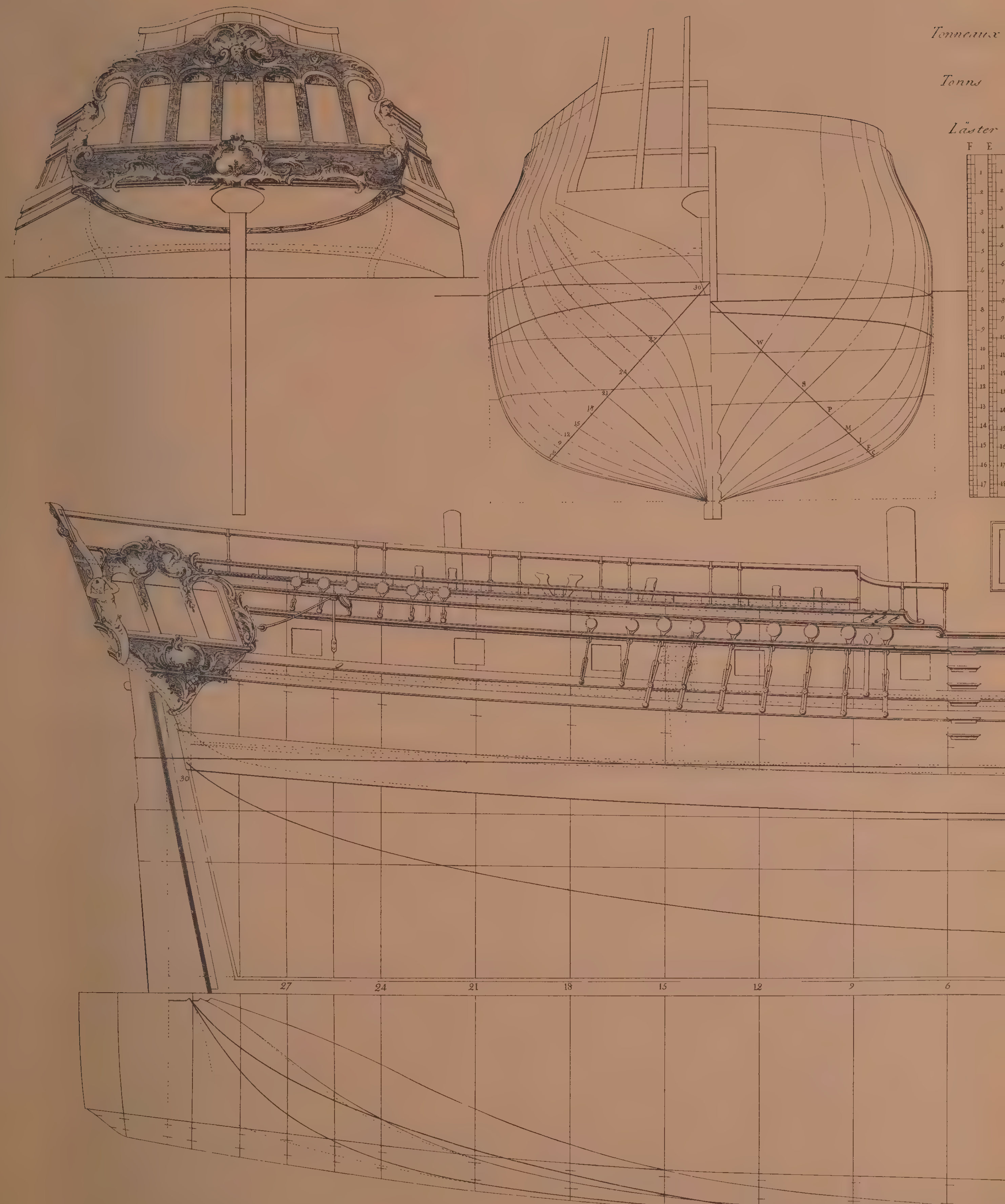
Hagboat viewed from starboard looking aft

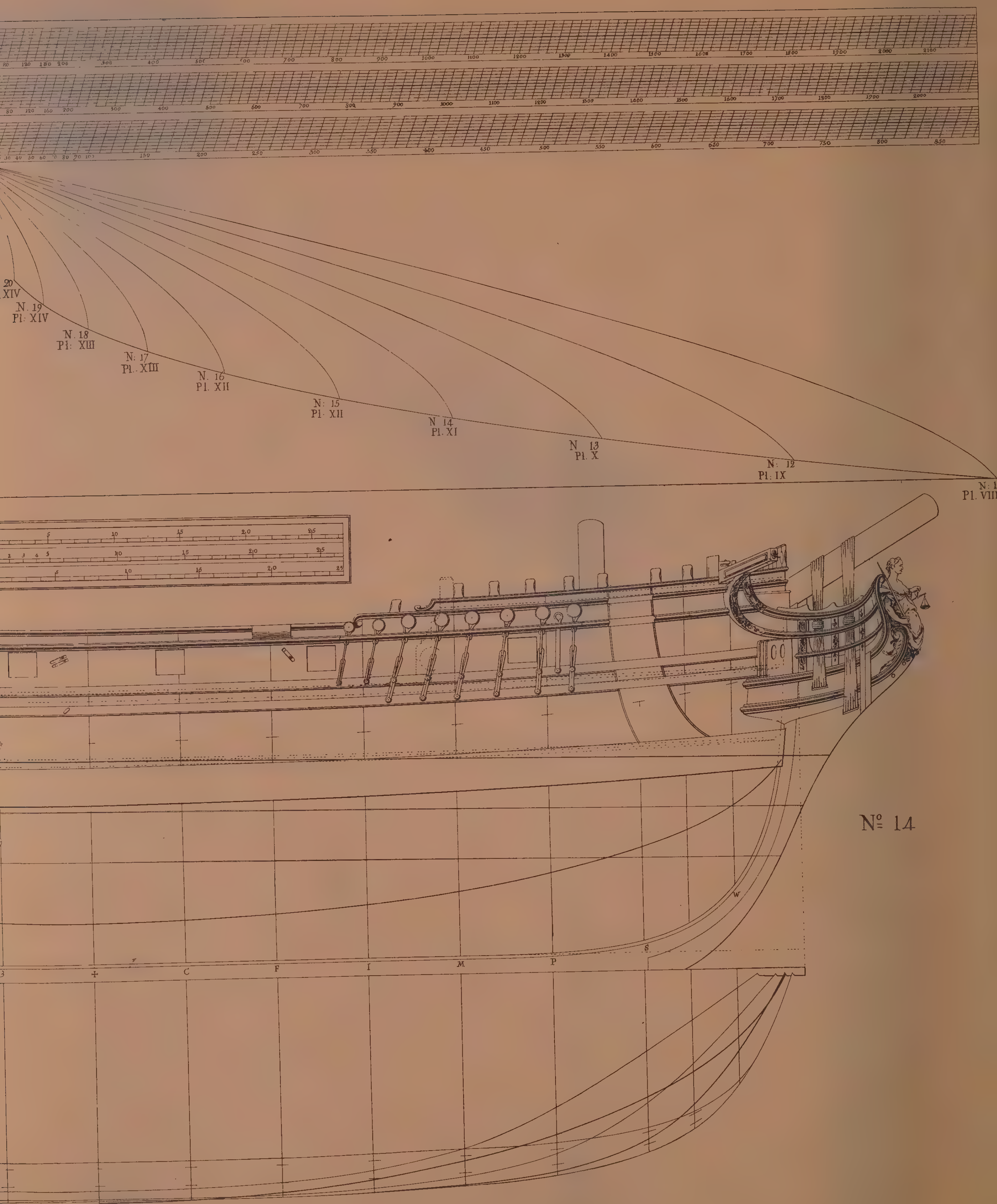
PLATE X

No 13 *Hagboat (Merchant vessels, 2nd class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	137ft
Breadth moulded	35 1/4ft
Draught as it is on the plan	18ft 9in
Draught laden	19ft 3in
Burthen	324 heavy lasts
Area of the midship frame	500 sq ft
Area of the load waterline	4030 sq ft
Displacement	47026 cu ft
Total cost of construction	50105 krone

above left:
Hagboat viewed from starboard looking forward


Tonneaux
Tonns
Läster
F E
27
24
21
18
15
12
9
6


N: 19
Pl: XIV
N. 18
Pl: XIII
N: 17
Pl.: XIII
N. 16
Pl. XII
N: 15
Pl: XII
N 14
Pl. XI
N 13
Pl. X
N: 12
Pl: IX
N: 11
Pl. VIII
C
F
I
M
P
S
W

Nº 14

PLATE XI

No 14 *Hagboat (Merchant vessels, 2nd class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	125ft
Breadth moulded	33ft
Draught as it is on the plan	17ft 3in
Draught laden	17ft 6in
Burthen	243 heavy lasts
Area of the midship frame	417 sqft
Area of the load waterline	3387 sqft
Displacement	35866 cuft
Total cost of construction	37205 krone

Note: The dotted lines in the after part of the ship show how the buttocks of a hagboat can be changed to those of a frigate.

above right:
Scale of burthen for hagboats and pinks
Plates VIII,11; IX,12; X,13; XI,14; XII,15; XII,16; XIII,17; XIII,18; XIV,19; XIV,20.
See page 99 for instructions on how to use the scale

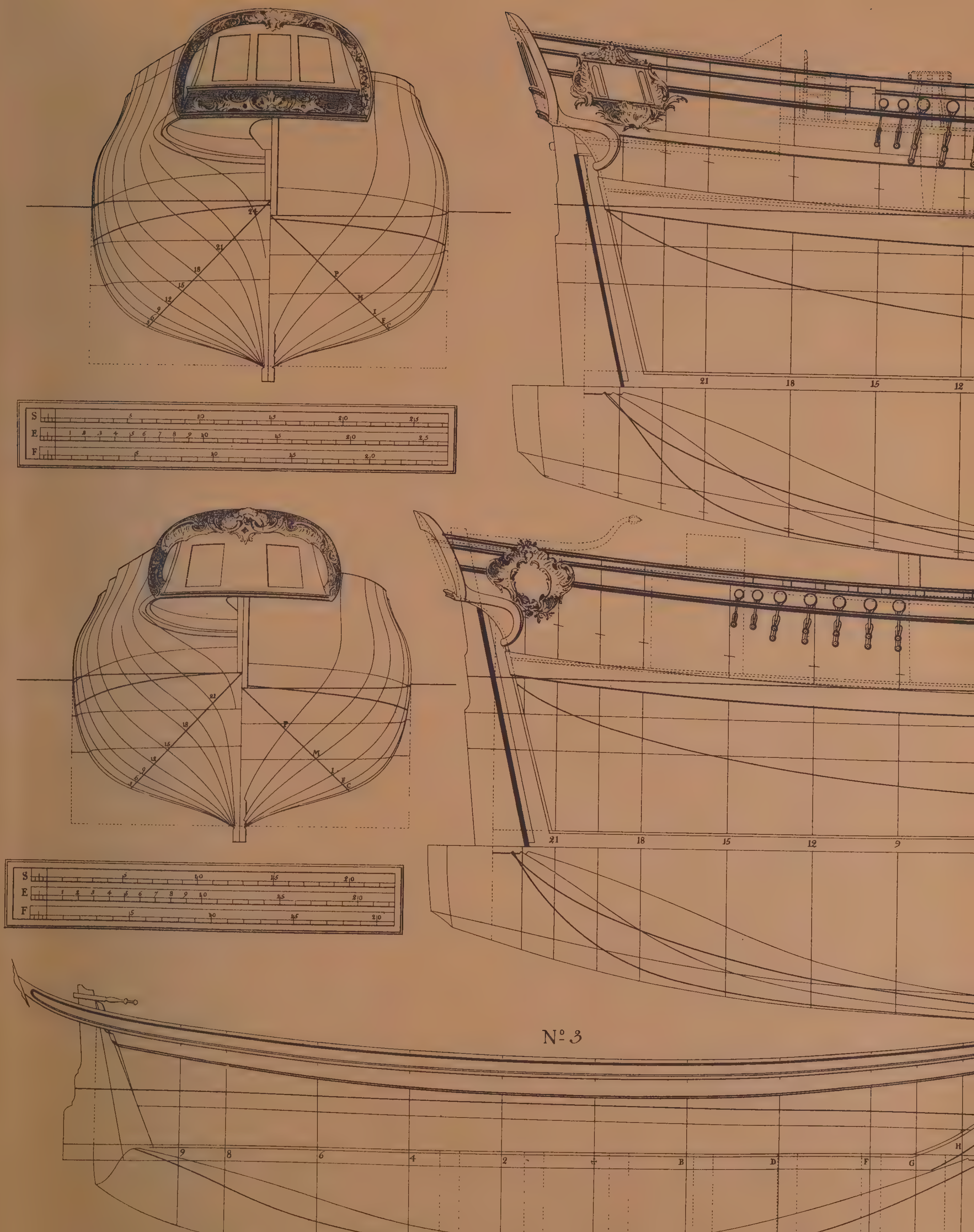
PLATE XII

No 15 *Pink (Merchant vessels, 3rd class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	113ft
Breadth moulded	30 1/3ft
Draught as it is on the plan	15ft 9in
Burthen	181 heavy lasts
Area of the midship frame	351 sqft
Area of the load waterline	2854 sqft
Displacement	27406 cu ft
Total cost of construction	26141 krone

No 16 *Pink (Merchant vessels, 3rd class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	101ft
Breadth moulded	27 1/2ft
Draught as it is on the plan	14ft 3in
Draught laden	14ft 9in
Burthen	138 heavy lasts
Area of the midship frame	278 sqft
Area of the load waterline	2271 sqft
Displacement	18700 cu ft
Total cost of construction	17054 krone


N° 3
S
E
F

Pl. XIII.

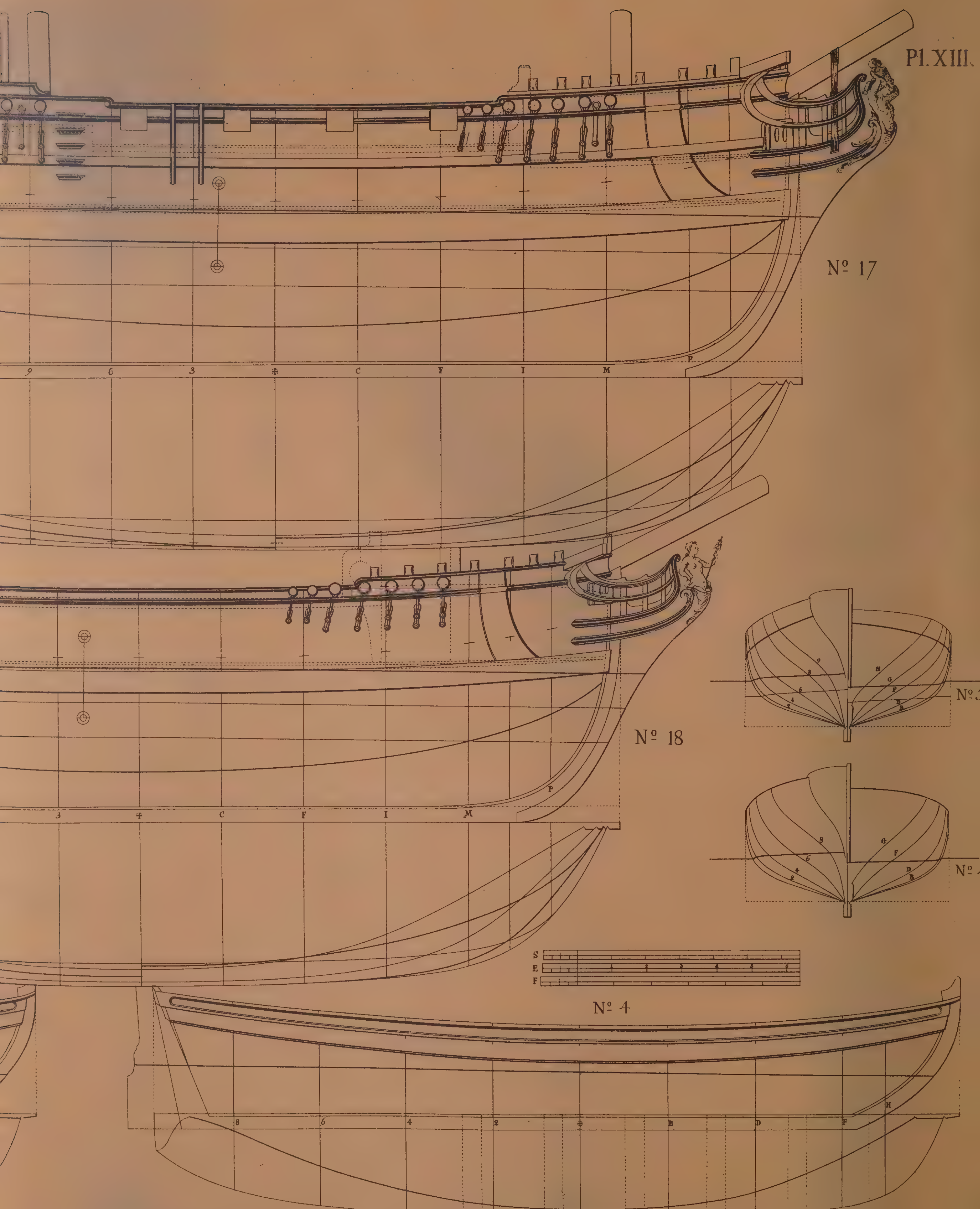


PLATE XIII

No 17 *Pink (Merchant vessels, 3rd class)*
with snow rigging (see plate LXII, No 2)

Length between perpendiculars	89ft
Breadth moulded	25ft
Draught as it is on the plan	12ft 9in
Draught laden	13ft 3in
Burthen	99 heavy lasts
Area of the midship frame	215 sq ft
Area of the load waterline	1789 sq ft
Displacement	12946 cu ft
Total cost of construction	11224 krone

No 18 *Pink (Merchant vessels, 3rd class)*
with brig rigging (see plate LXII, No 4)

Length between perpendiculars	77ft
Breadth moulded	221/4ft
Draught as it is on the plan	11ft
Draught laden	11ft 6in
Burthen	67 heavy lasts
Area of the midship frame	161 sq ft
Area of the load waterline	1369 sq ft
Displacement	8380 cu ft
Total cost of construction	6797 krone

No 3 *Pinnace (Boats for the use of ships)*

Length between perpendiculars	27ft
Breadth moulded	6ft
Pairs of oars	7

No 4 *Pinnace (Boats for the use of ships)*

Length between perpendiculars	24ft
Breadth moulded	5ft 11in
Pairs of oars	5

PLATE XIV

No 19 *Pink (Merchant vessels, 3rd class)*
with brig rigging (see plate LXII, No 4)

Length between perpendiculars	65ft
Breadth moulded	19 1/4ft
Draught as it is on the plan	9ft 6in
Draught laden	10ft
Burthen	40 heavy lasts
Area of the midship frame	112 sqft
Area of the load waterline	980 sqft
Displacement	4872 cuft
Total cost of construction	3783 krone

No 20 *Pink (Merchant vessels, 3rd class)*
with sloop rigging (see plate LXII, No 12)

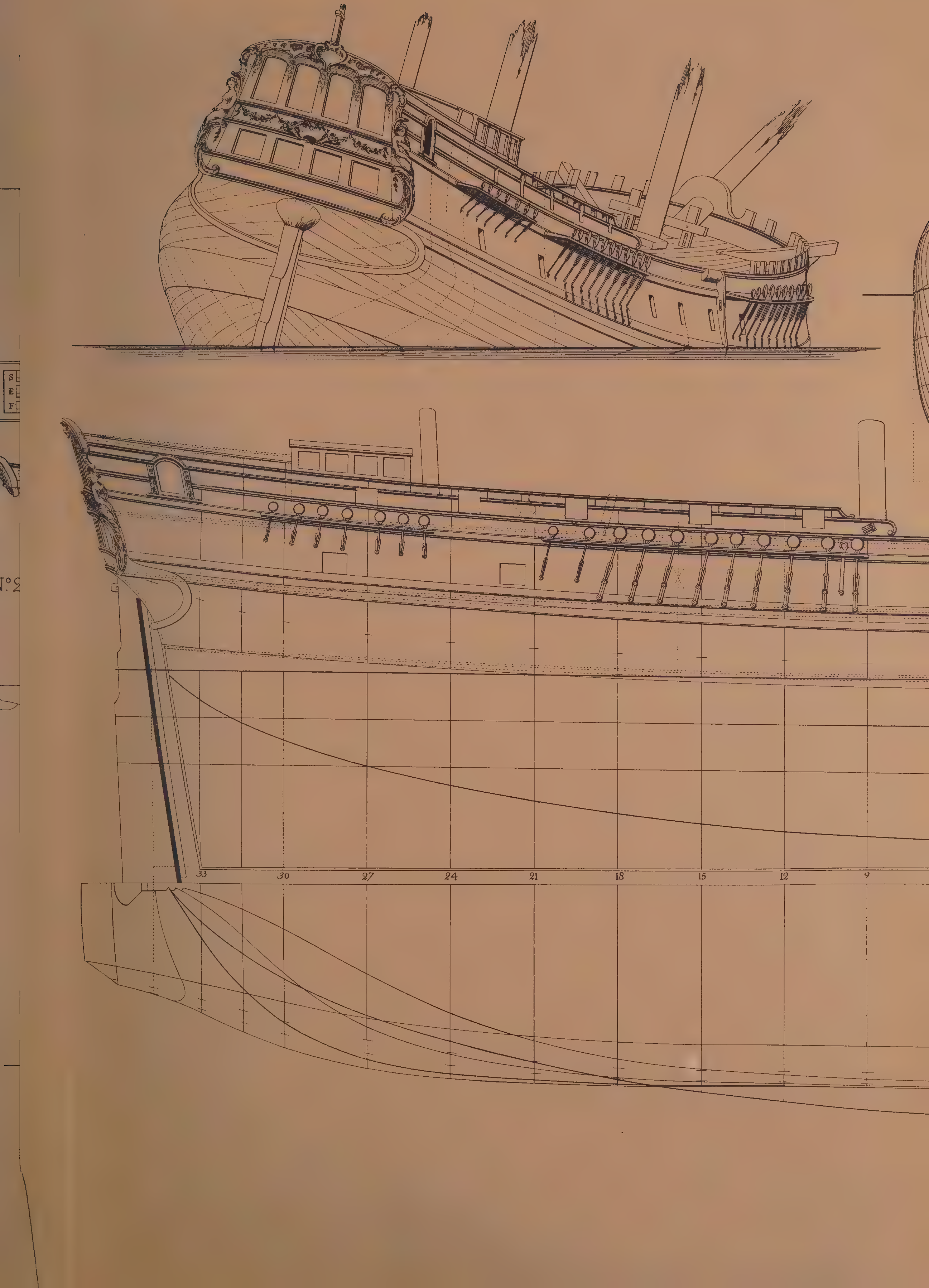
Length between perpendiculars	53ft
Breadth moulded	17ft
Draught as it is on the plan	8ft
Draught laden	8ft 6in
Burthen	24 heavy lasts
Area of the midship frame	81 sqft
Area of the load waterline	698 sqft
Displacement	2784 cuft
Total cost of construction	2122 krone

No 5 *Bark (Merchant vessels, small draught of water)*
with galeass rigging (see plate LXII, No 9)

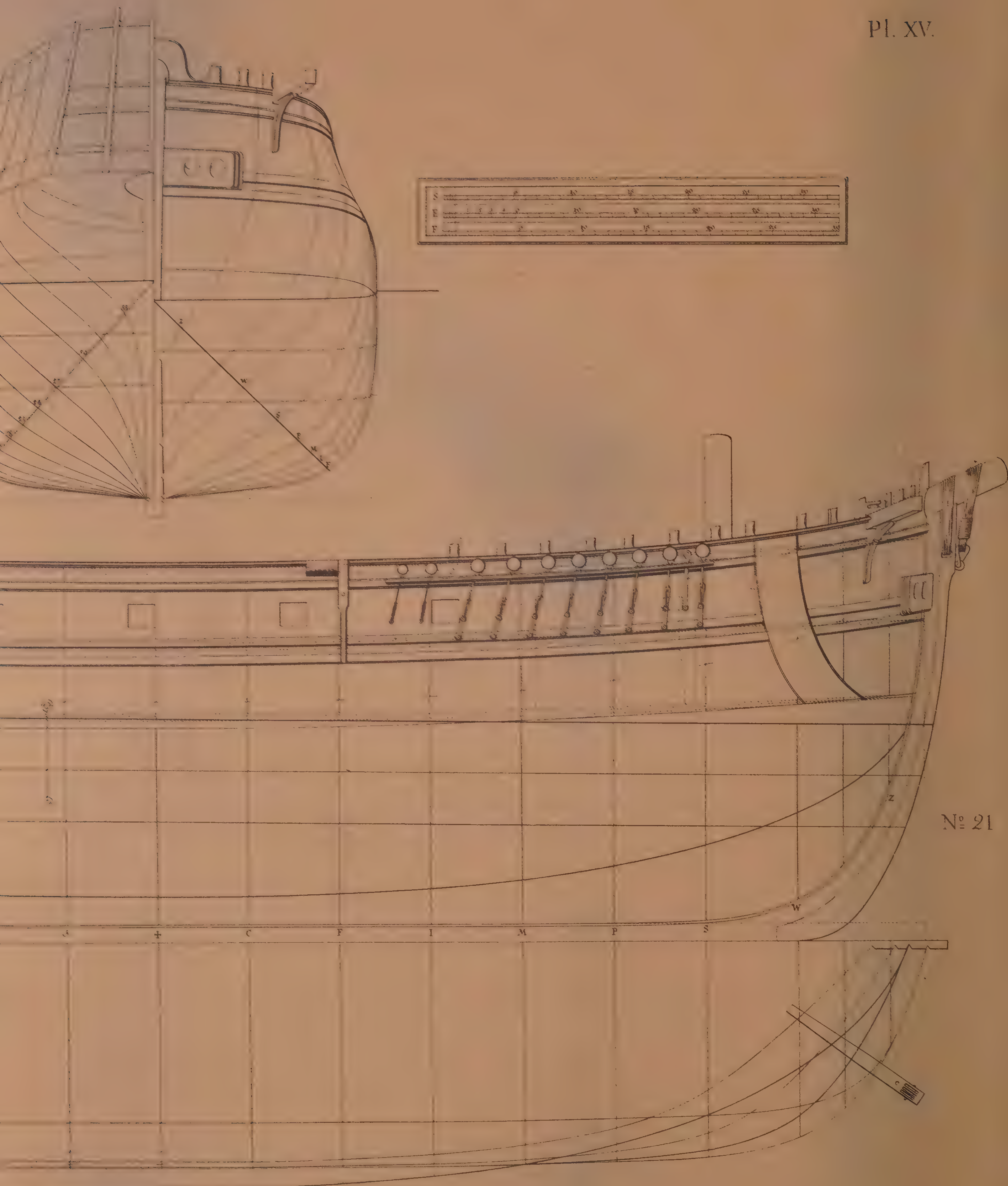
Length between perpendiculars	70ft
Breadth moulded	20ft
Draught as it is on the plan	8ft
Draught laden	8ft 9in
Burthen	50 heavy lasts
Area of the midship frame	115 sqft
Area of the load waterline	1139 sqft
Displacement	5526 cuft
Total cost of construction	4012 krone

No 1 *Launch (Boats for the use of ships)*

Length between perpendiculars	37 1/2ft
Breadth moulded	10ft
Pairs of oars	8


S
E
F
N°2
33
30
27
24
21
18
15
12
9

Pl. XV.



Nº 21

PLATE XV

No 21 *Cat (Merchant vessels, 4th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	157ft
Breadth moulded	38 1/2ft
Draught as it is on the plan	20ft
Burthen	467 heavy lasts
Area of the midship frame	611 sqft
Area of the load waterline	5295 sqft
Displacement	70682 cuft
Total cost of construction	79648 krone

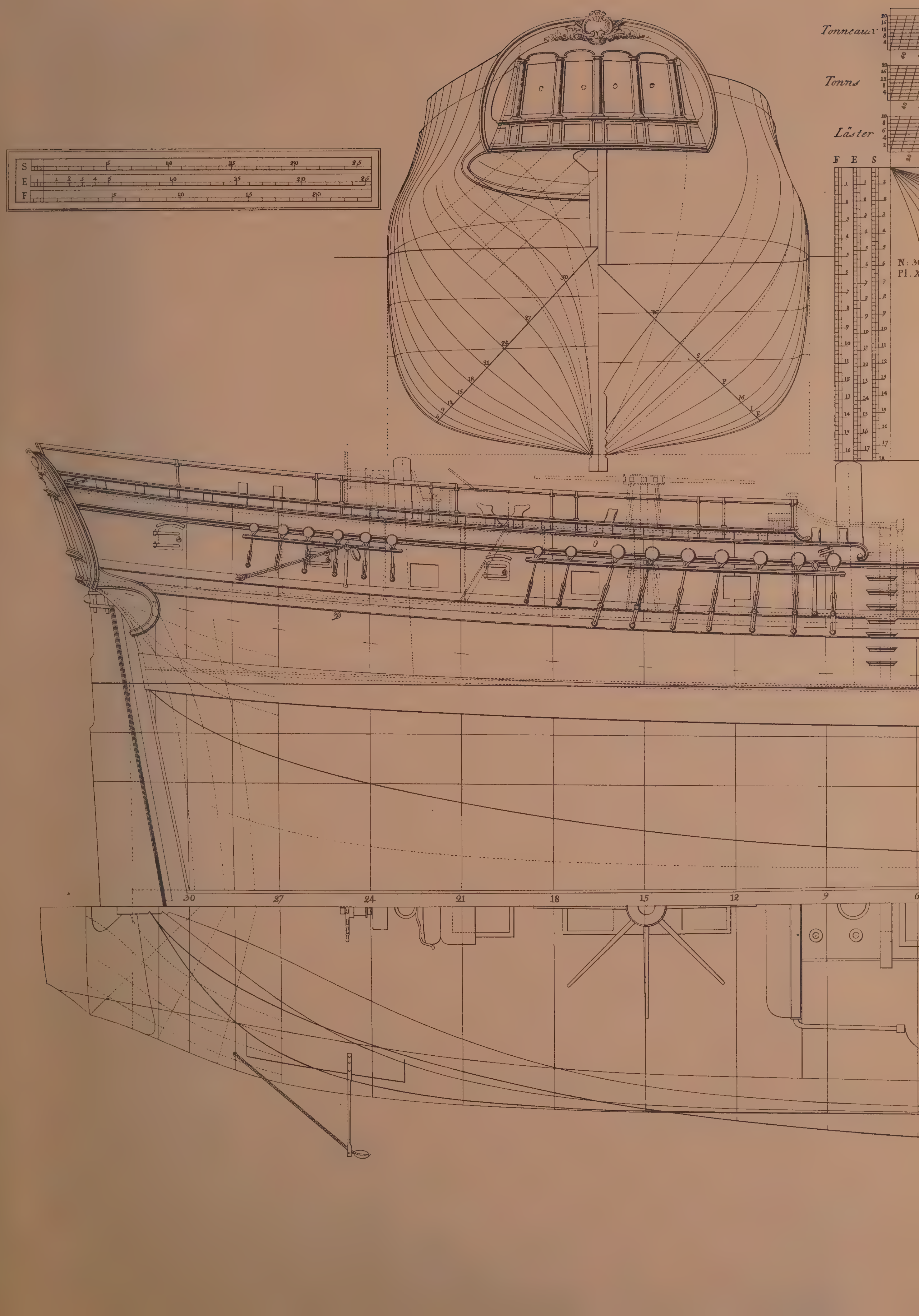
above left:
vessel heeling over

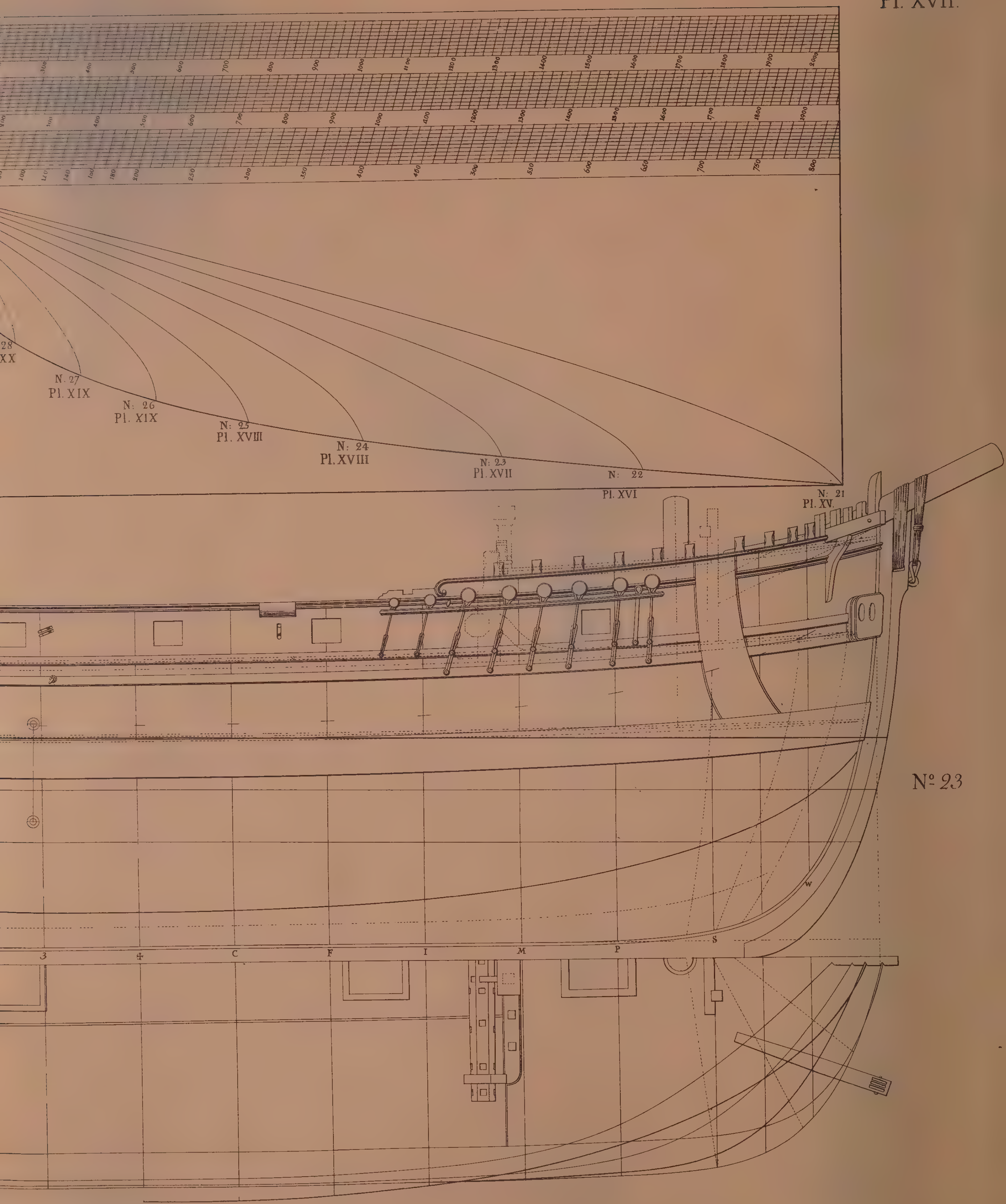
PLATE XVI

No 22 *Cat (Merchant vessels, 4th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	146ft
Breadth moulded	36 1/3ft
Draught as it is on the plan	19ft
Burthen	374 heavy lasts
Area of the midship frame	530 sqft
Area of the load waterline	4595 sqft
Displacement	55903 cuft
Total cost of construction	60752 krone

above left:
figure of the ship careened


Tonneaux
Tonns
Läster
F E S


N: 28
XX
N: 27
Pl. XIX
N: 26
Pl. XIX
N: 25
Pl. XVIII
N: 24
Pl. XVIII
N: 23
Pl. XVII
N: 22
Pl. XVI
N: 21
Pl. XV.
3
C
F
I
M
P
S
W

Nº 23

PLATE XVII

No 23 *Cat (Merchant vessels, 4th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	134ft
Breadth moulded	34ft
Draught as it is on the plan	18ft
Draught laden	18ft 6in
Burthen	326 heavy lasts
Area of the midship frame	468 sq ft
Area of the load waterline	3902 sq ft
Displacement	45228 cu ft
Total cost of construction	45047 krone

above right:
Scale of burthen for cats
Plates XV,21; XVI,22; XVII,23; XVIII,24; XVIII,25; XIX,26; XIX,27; XX,28; XX,29; XX,30.
See page 99 for instructions on how to use the scale

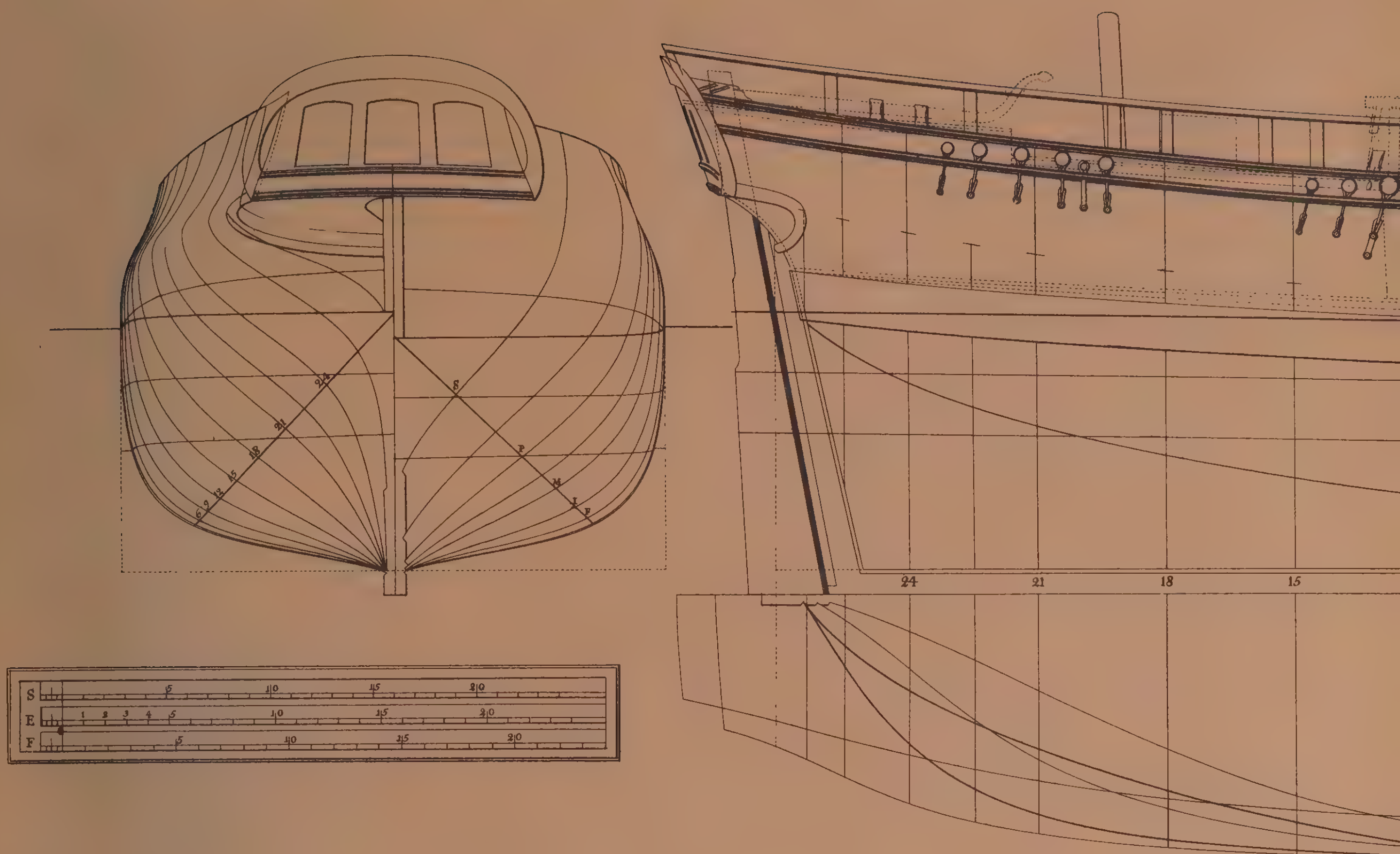
PLATE XVIII

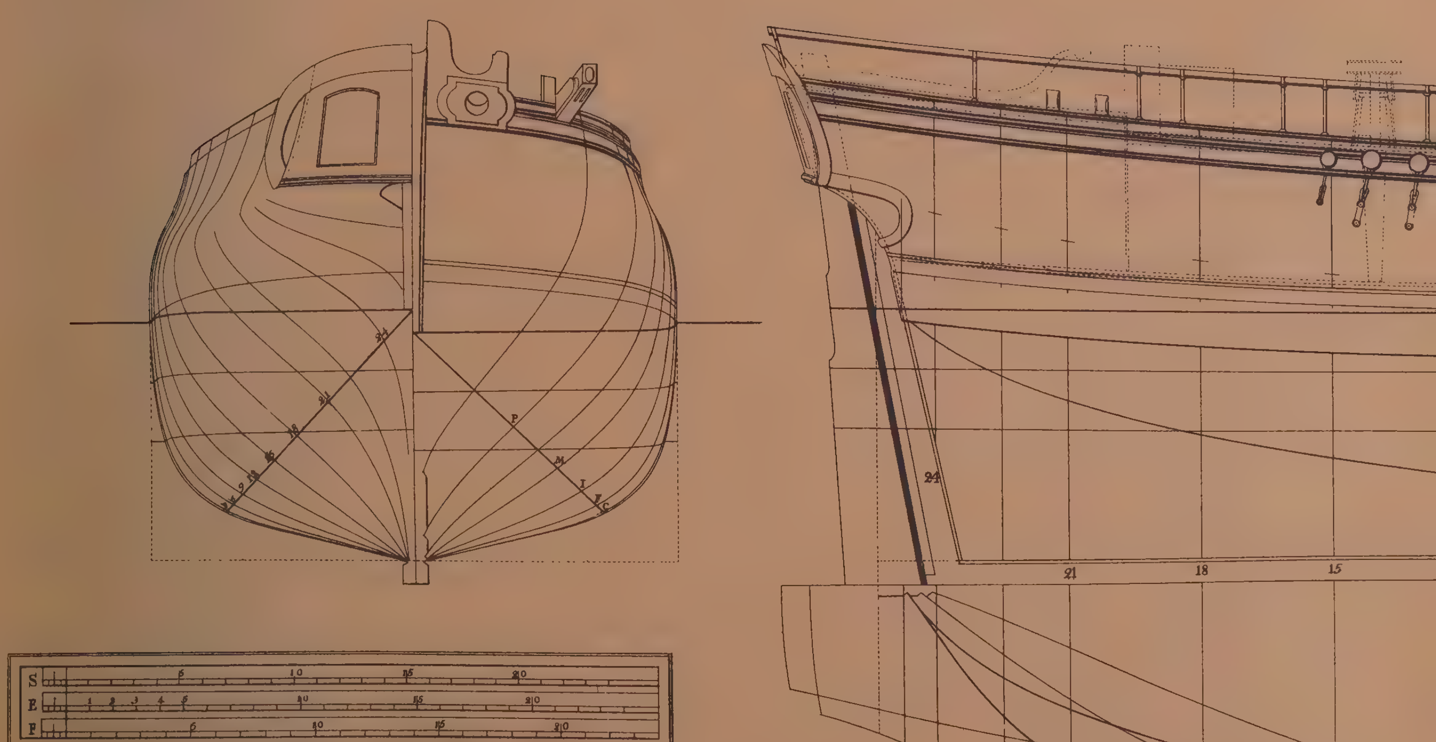
No 24 *Cat (Merchant vessels, 4th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	122ft
Breadth moulded	31 1/3ft
Draught as it is on the plan	16ft 6in
Draught laden	17ft 3in
Burthen	261 heavy lasts
Area of the midship frame	369 sqft
Area of the load waterline	3265 sqft
Displacement	34494 cuft
Total cost of construction	32118 krone

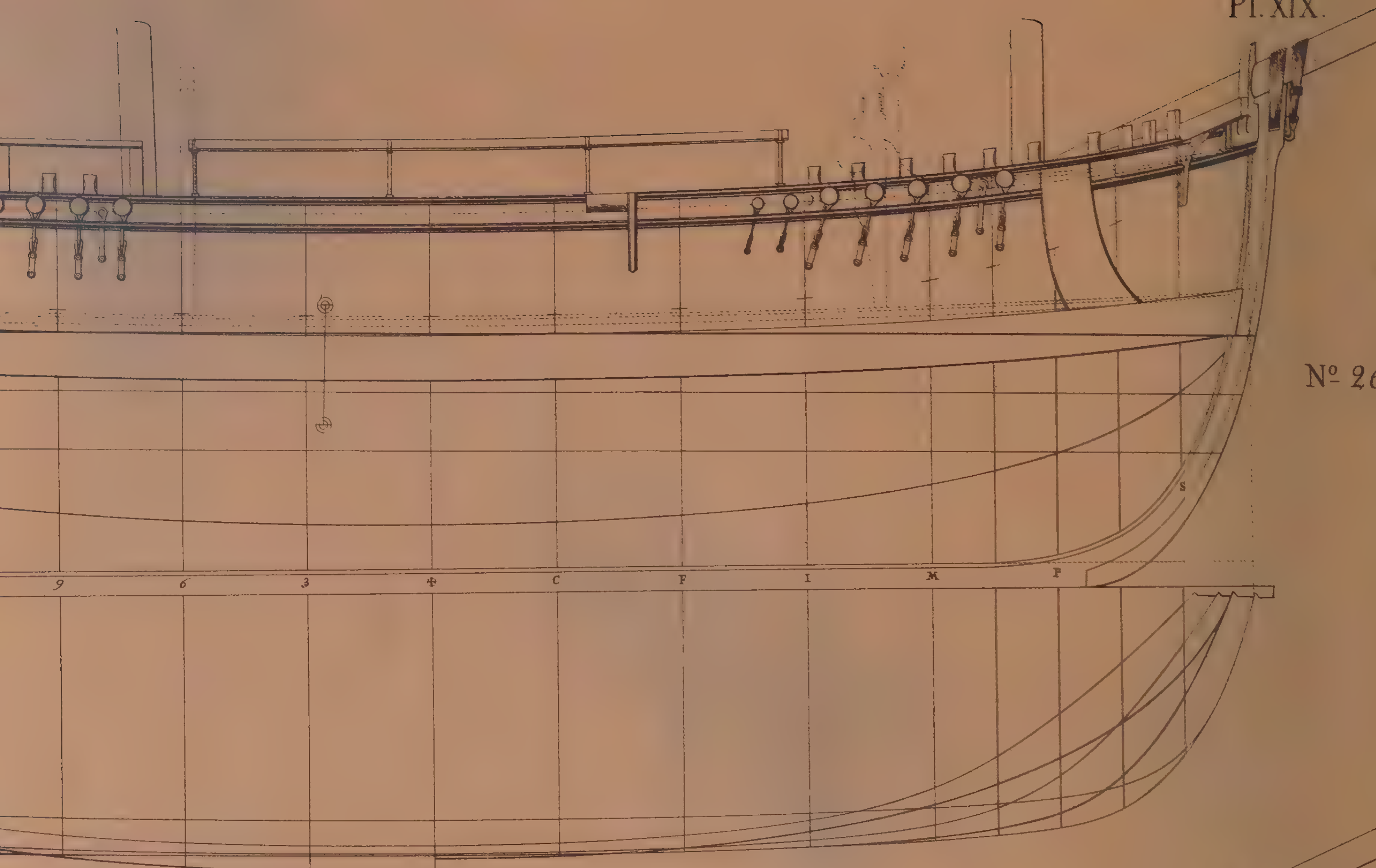
No 25 *Cat (Merchant vessels, 4th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	110ft
Breadth moulded	28 3/4ft
Draught as it is on the plan	15ft 4in
Draught laden	15ft 10in
Burthen	191 heavy lasts
Area of the midship frame	329 sqft
Area of the load waterline	2634 sqft
Displacement	25186 cuft
Total cost of construction	22734 krone

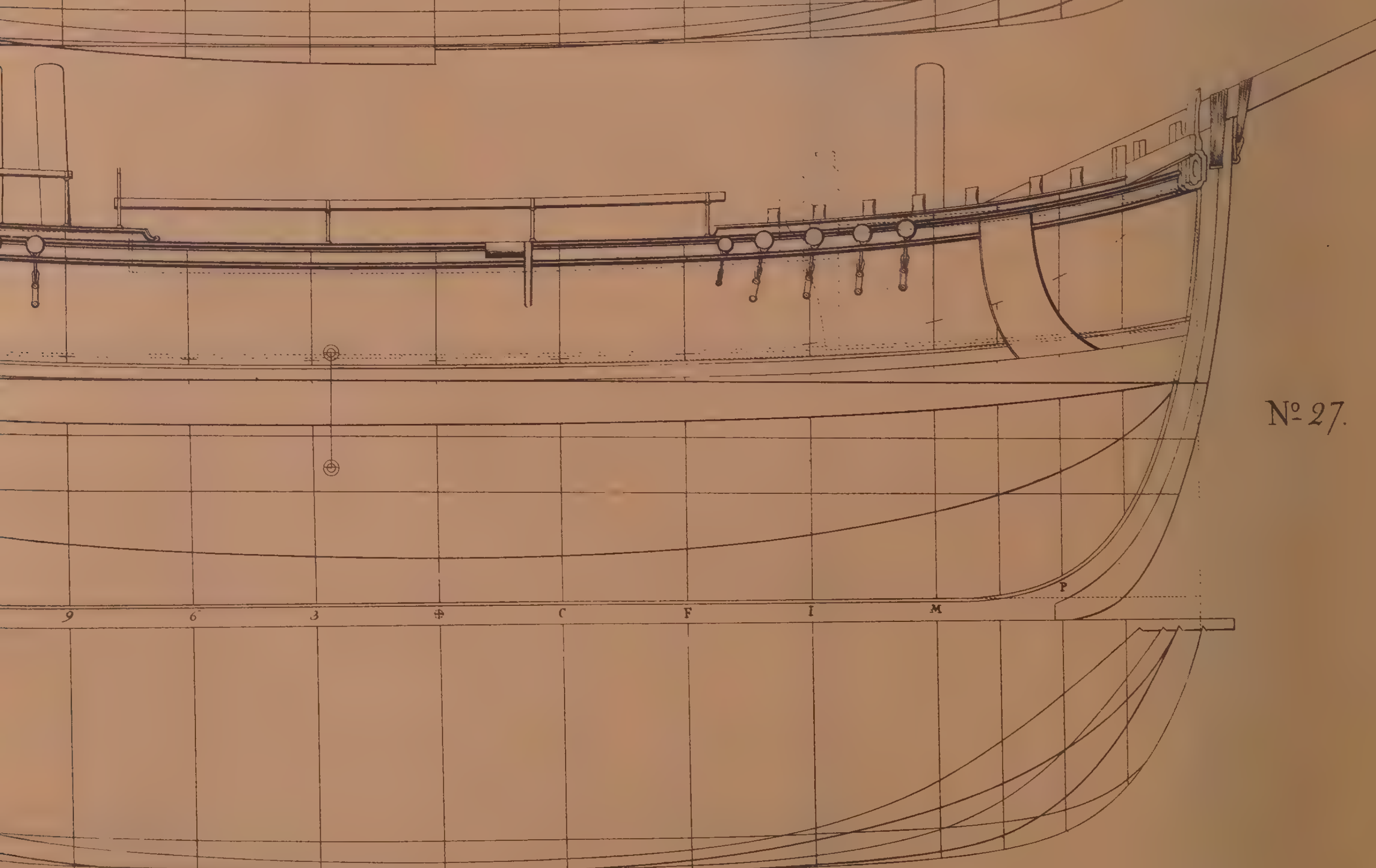

24
21
18
15
S
E
F


24
21
18
15
S
E
F

Pl. XIX.



Nº 26.



Nº 27.

PLATE XIX

No 26 *Cat (Merchant vessels, 4th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	98ft
Breadth moulded	26 1/4ft
Draught as it is on the plan	13ft 8in
Draught laden	14ft 2in
Burthen	142 heavy lasts
Area of the midship frame	261 sq ft
Area of the load waterline	2194 sq ft
Displacement	18404 cu ft
Total cost of construction	14962 krone

No 27 *Cat (Merchant vessels, 4th class)*
with snow rigging (see plate LXII, No 2)

Length between perpendiculars	86ft
Breadth moulded	23 1/2ft
Draught as it is on the plan	12ft 3in
Draught laden	12ft 9in
Burthen	99 heavy lasts
Area of the midship frame	205 sq ft
Area of the load waterline	1696 sq ft
Displacement	12478 cu ft
Total cost of construction	10017 krone

PLATE XX

No 5 *Yawl (Boats for the use of ships)*

Length between perpendiculars	20ft
Breadth moulded	6ft
Pairs of oars	5

No 6 *Yawl (Boats fot the use of ships)*

Length between perpendiculars	18ft
Breadth moulded	5 1/4ft
Pairs of oars	4

No 28 *Cat (Merchant vessels, 4th class)*
with brig rigging (see plate LXII, No 4)

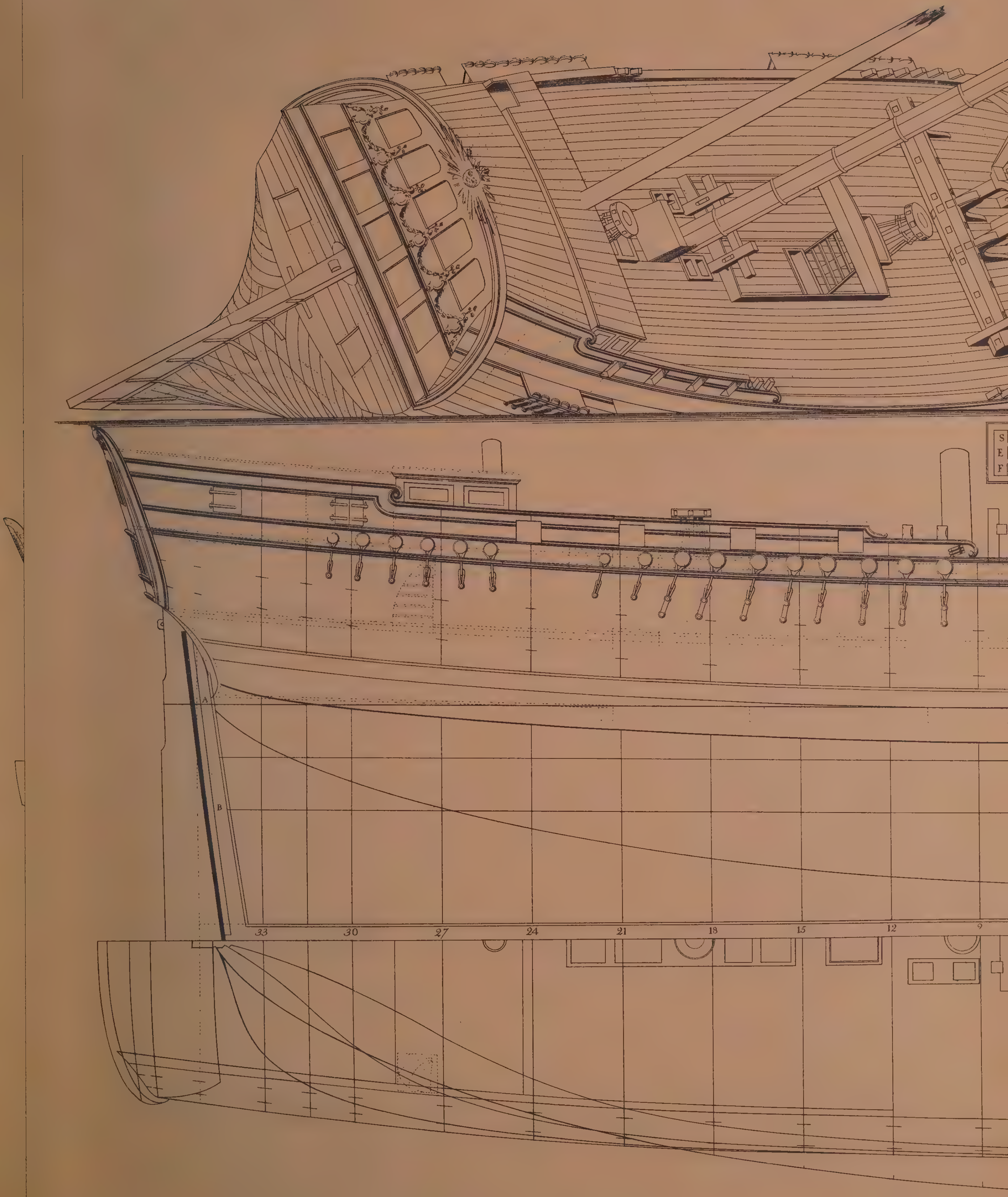
Length between perpendiculars	74ft
Breadth moulded	20 3/4ft
Draught as it is on the plan	10ft 6in
Draught laden	11ft 3in
Burthen	67 heavy lasts
Area of the midship frame	149 sqft
Area of the load waterline	1268 sqft
Displacement	7590 cuft
Total cost of construction	5488 krone

No 29 *Cat (Merchant vessels, 4th class)*
with sloop rigging (see plate LXII, No 12)

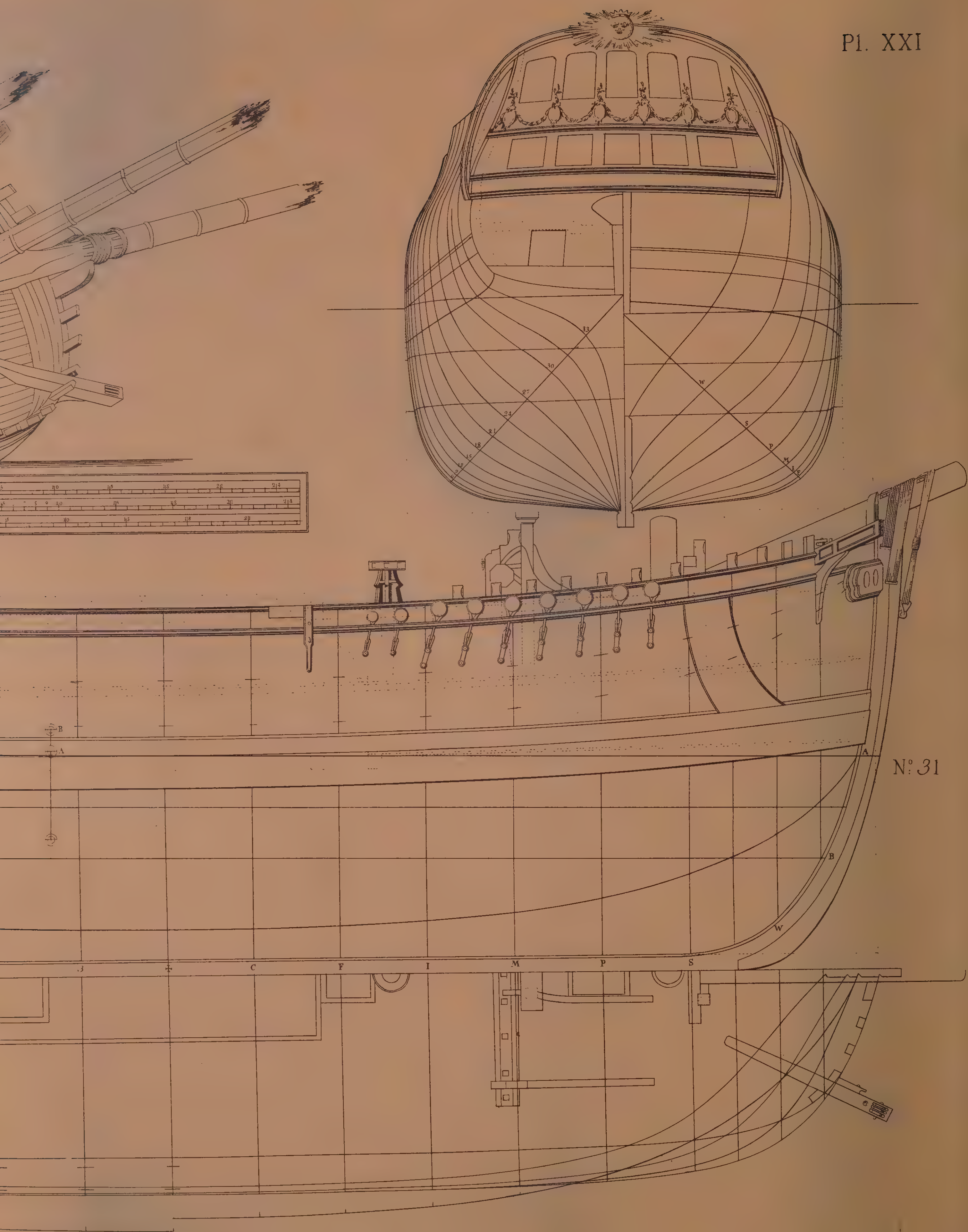
Length between perpendiculars	62ft
Breadth moulded	18 1/2ft
Draught as it is on the plan	9ft
Draught laden	9ft 9in
Burthen	45 heavy lasts
Area of the midship frame	111 sqft
Area of the load waterline	939 sqft
Displacement	4768 cuft
Total cost of construction	3237 krone

No 30 *Cat (Merchant vessels, 4th class)*
with sloop rigging (see plate LXII, No 12)

Length between perpendiculars	45ft
Breadth moulded	15 3/4ft
Draught as it is on the plan	7ft 4in
Draught laden	7ft 7in
Burthen	22 heavy lasts
Area of the midship frame	68 sqft
Area of the load waterline	650 sqft
Displacement	2488 cuft
Total cost of construction	2631 krone



A
B
33
30
27
24
21
18
15
12
9



N° 31

PLATE XXI

No 31 *Bark (Merchant vessels, 5th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	155ft
Breadth moulded	39ft
Draught as it is on the plan	20ft 6in
Draught laden	21ft 3in
Burthen	521 heavy lasts
Area of the midship frame	636 sqft
Area of the load waterline	5185 sqft
Displacement	71772 cuft
Total cost of construction	79473 krone

Note:

drawn on the sheer draught are:
A the metacenter for waterline A—A
B the metacenter for waterline B—B

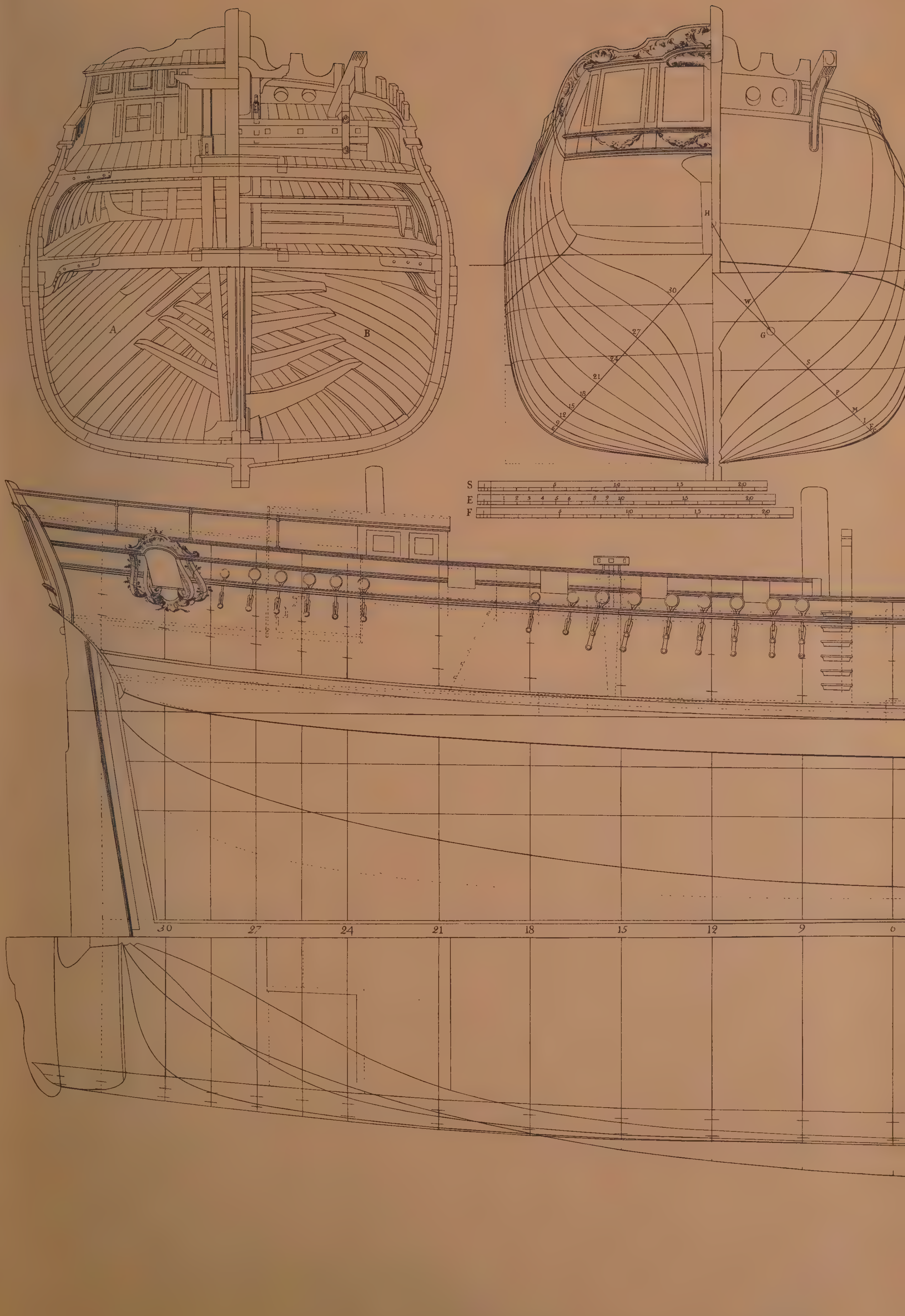
above left:

view of the deck when the ship is careened

PLATE XXII

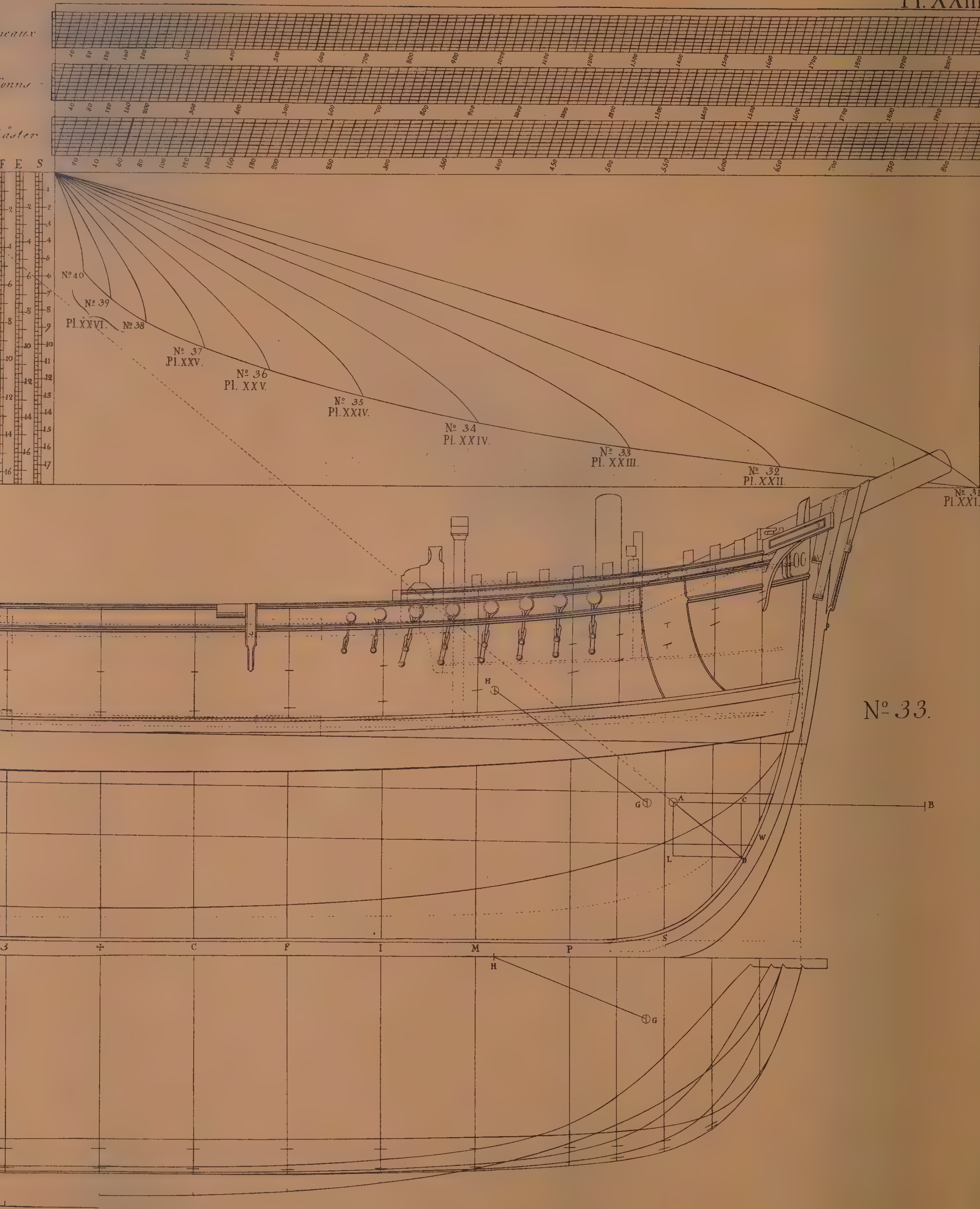
No 32 *Bark (Merchant vessels, 5th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	142 1/2ft
Breadth moulded	34 2/3ft
Draught as it is on the plan	19ft
Draught laden	20ft
Burthen	426 heavy lasts
Area of the midship frame	531 sqft
Area of the load waterline	4338 sqft
Displacement	56272 cuft
Total cost of construction	59773 krone



A
B
H
W
G
S
P
M
30
27
24
21
18
15
12
S
E
F
5
10
15
20
1 2 3 4 5 6 8 9 10
30 27 24 21 18 15 12 9 6

Pl. XXIII.



N° 40
N° 39
Pl. XXVI.
N° 38
N° 37
Pl. XXV.
N° 36
Pl. XXV.
N° 35
Pl. XXIV.
N° 34
Pl. XXIV.
N° 33
Pl. XXIII.
N° 32
Pl. XXII.
N° 31
Pl. XXI.

N° 33.

PLATE XXIII

No 33 *Bark (Merchant vessels, 5th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	131ft
Breadth moulded	33ft
Draught as it is on the plan	17ft 9in
Draught laden	18ft 6in
Burthen	335 heavy lasts
Area of the midship frame	467 sq ft
Area of the load waterline	3791 sq ft
Displacement	44864 cu ft
Total cost of construction	41727 krone

above left:

A—view looking aft from the midship frame

B—view looking forward from the midship frame

above right:

scale of burthen for barks:

Plates XXI,31; XXII,32; XXIII,33; XXIV,34; XXIV,35; XXV,36; XXV,37; XXVI,38; XXVI,39; XXVI,40

See page 99 for instructions on how to use the scale.

Note:

on this draught the points have been marked where the center of effort of the sails is to be found, as well as the mean direction of the water if it is supposed that the water abaft the greatest breadth meets with no increased or diminished resistance when the ship is in motion.

Line *AB* denotes the resistance met with by a plane similar to that of the midship section when water strikes against it at the head of the ship at a certain velocity. *AC* denotes the direct resistance at the bow, if it is supposed that the velocity is the same as that in the aforementioned plane: *AL* denotes the perpendicular resistance. The resultant diagonal *DA* is the mean resistance of the water when the ship is sailed before the wind. This mean resistance is always the same at any velocity, as for example the highest velocity of the vessel.

F is the center of gravity of the waterline and line *FE* is perpendicular to it. *DA* is extended to cut *FE* at point *E*, which gives the height at which the center of effort of the sails must lie above the waterline, provided that the ship is not suddenly immersed too deeply, but that the bow lifts and that she is sailed before the wind.

If the vessel is sailing on the wind with, let us say, half a point of leeway and heeling at an angle of 7°, then it can be said that the mean direction of the water resistance is concentrated at point *G*; the direction is along line *GH* and point *H* is where the mean direction meets a given plane along the center line of the ship passing through the keel, stem and sternpost.

I is the center of gravity of the displacement and *K* the metacenter.

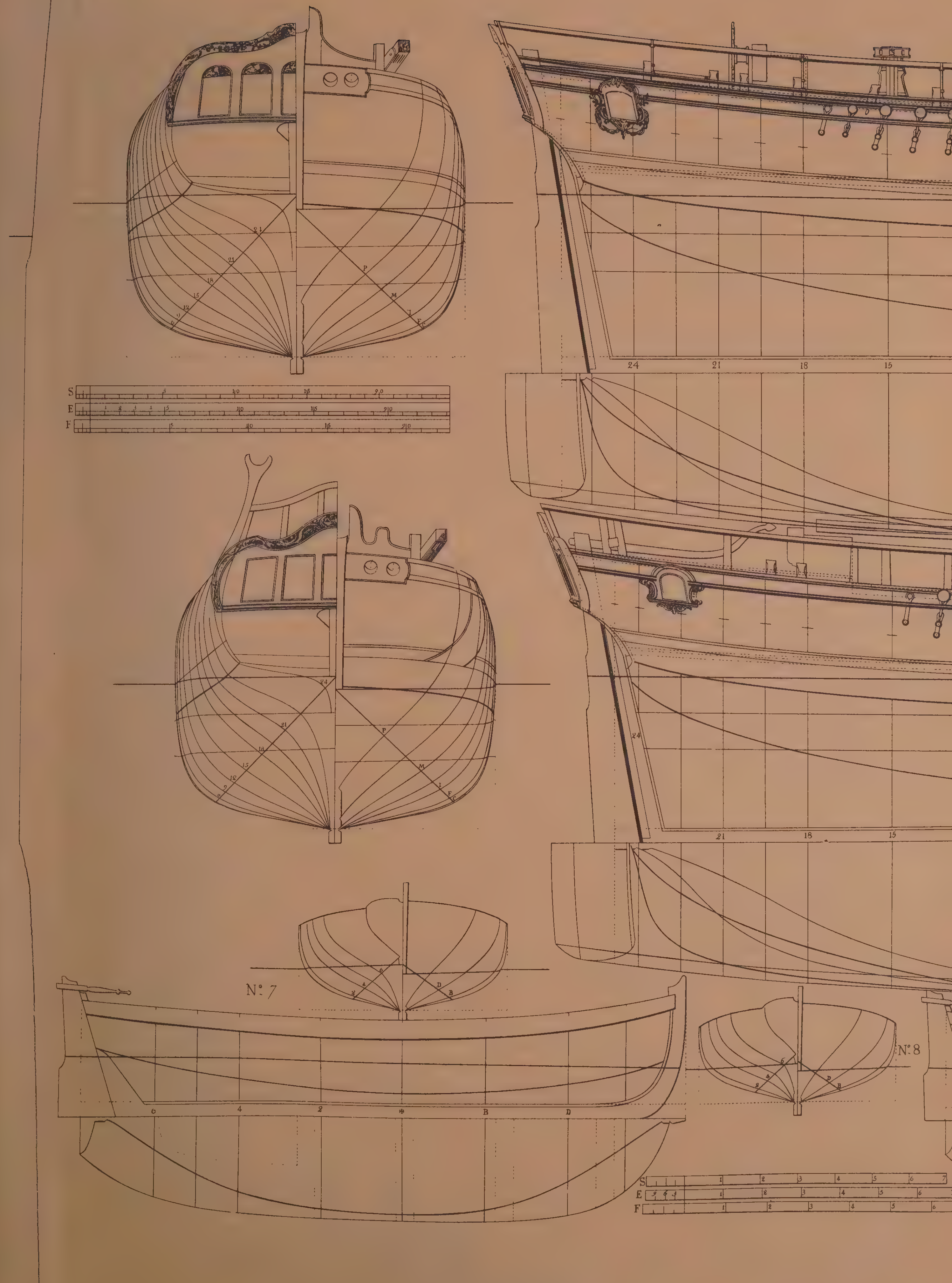
PLATE XXIV

No 34 *Bark (Merchant vessels, 5th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	119ft
Breadth moulded	30 2/3ft
Draught as it is on the plan	16ft 6in
Draught laden	17ft
Burthen	244 heavy lasts
Area of the midship frame	387 sq ft
Area of the load waterline	3116 sq ft
Displacement	32972 cu ft
Total cost of construction	29652 krone

No 35 *Bark (Merchant vessels, 5th class)*
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	107ft
Breadth moulded	27 5/6ft
Draught as it is on the plan	14ft 7in
Draught laden	15ft 1in
Burthen	182 heavy lasts
Area of the midship frame	310 sq ft
Area of the load waterline	2541 sq ft
Displacement	23909 cu ft
Total cost of construction	19965 krone


N° 7
N° 8

Pl. XXV.

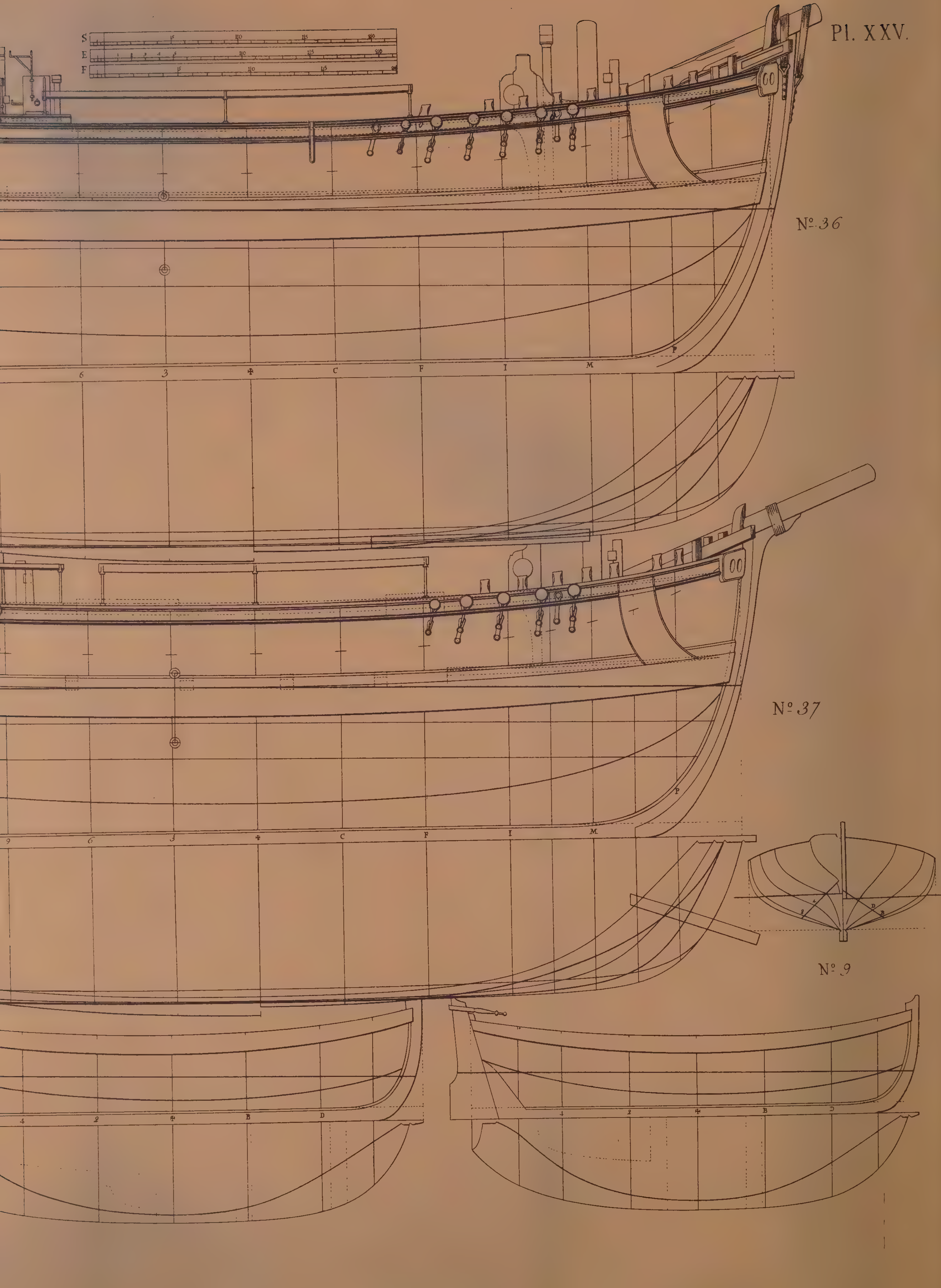


PLATE XXV

No 36 *Bark (Merchant vessels, 5th class)*
with snow rigging (see plate LXII, No 2)

Length between perpendiculars	95ft
Breadth moulded	245/6ft
Draught as it is on the plan	13ft 2in
Draught laden	13ft 8in
Burthen	131 heavy lasts
Area of the midship frame	246 sqft
Area of the load waterline	2019 sqft
Displacement	16632 cuft
Total cost of construction	13976 krone

No 37 *Bark (Merchant vessels, 5th class)*
with brig rigging (see plate LXII, No 4)

Length between perpendiculars	83ft
Breadth moulded	221/4ft
Draught as it is on the plan	11ft 6in
Draught laden	11ft 9in
Burthen	89 heavy lasts
Area of the midship frame	194 sqft
Area of the load waterline	1582 sqft
Displacement	11583 cuft
Total cost of construction	8654 krone

No 7 *Yawl (Boats for the use of ships)*

Length between perpendiculars	16ft
Breadth moulded	51/2ft
Pairs of oars	4

No 8 *Yawl (Boats for the use of ships)*

Length between perpendiculars	14ft
Breadth moulded	51/4ft
Pairs of oars	3

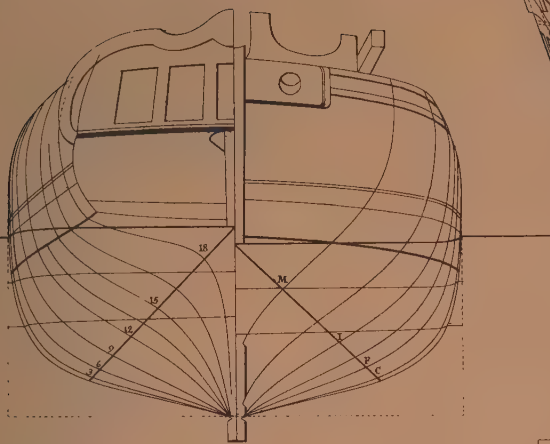
No 9 *Yawl (Boats for the use of ships)*

Length between perpendiculars	12ft
Breadth moulded	5ft
Pairs of oars	3

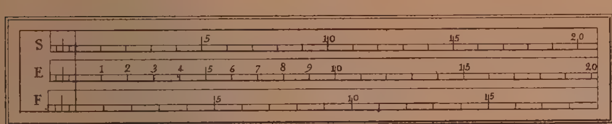
PLATE XXVI

No 1	*Pinnace (Boats for the use of ships)*	
	Length between perpendiculars	33ft
	Breadth moulded	6 1/2ft
	Pairs of oars	10
No 4	*Launch (Boats for the use of ships)*	
	Length between perpendiculars	20ft
	Breadth moulded	6ft
	Pairs of oars	5
No 38	*Bark (Merchant vessels, 5th class)*	
	with brig rigging (see plate LXII, No 4)	
	Length between perpendiculars	71ft
	Breadth moulded	20ft
	Draught as it is on the plan	10ft
	Draught laden	10ft 3in
	Burthen	57 heavy lasts
	Area of the midship frame	144 sq ft
	Area of the load waterline	1202 sq ft
	Displacement	7096 cu ft
	Total cost of construction	5075 krone
No 39	*Bark (Merchant vessels, 5th class)*	
	with sloop rigging (see plate LXII, No 12)	
	Length between perpendiculars	59ft
	Breadth moulded	18 1/4ft
	Draught as it is on the plan	6ft 6in
	Draught laden	6ft 9in
	Burthen	35 heavy lasts
	Area of the midship frame	107 sq ft
	Area of the load waterline	899 sq ft
	Displacement	3410 cu ft
	Total cost of construction	2930 krone
No 40	*Bark (Merchant vessels, 5th class)*	
	with sloop rigging (see plate LXII, No 12)	
	Length between perpendiculars	47 1/4ft
	Breadth moulded	15 1/2ft
	Draught as it is on the plan	6ft 10in
	Draught laden	7ft 1in
	Burthen	19 heavy lasts
	Area of the midship frame	69 sq ft
	Area of the load waterline	584 sq ft
	Displacement	2146 cu ft
	Total cost of construction	1404 krone

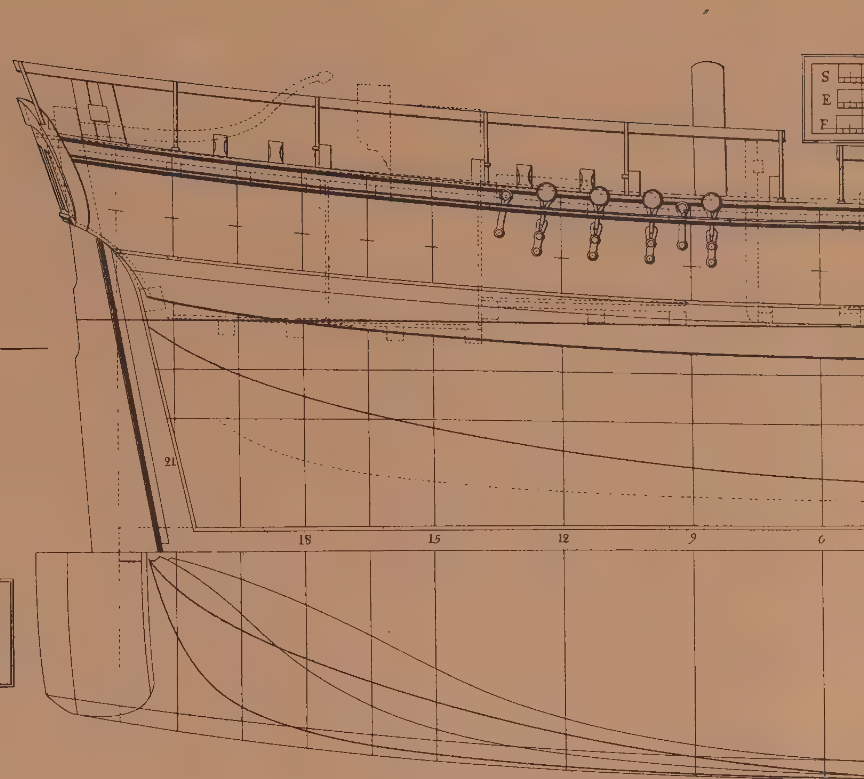
Nº 39



18
15
12
9
6
3
M
I
F
C

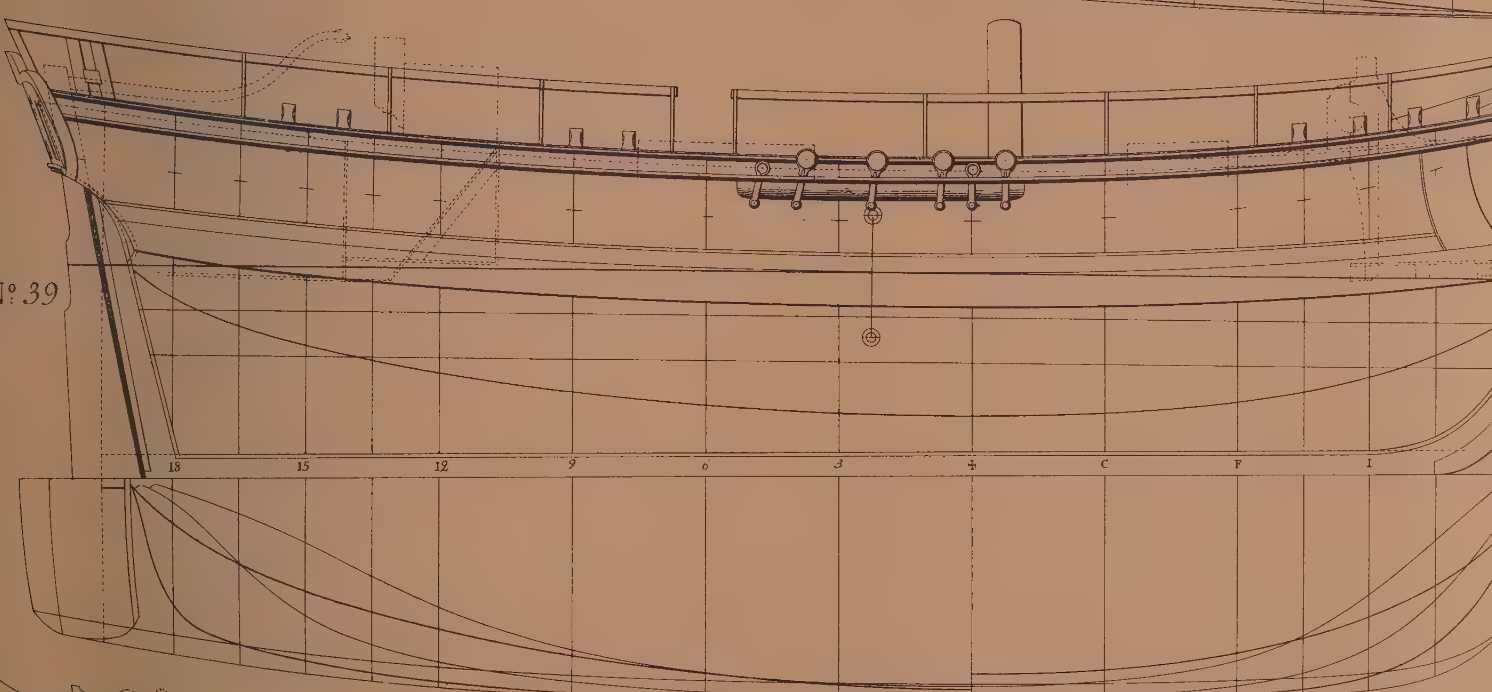


S
E
F

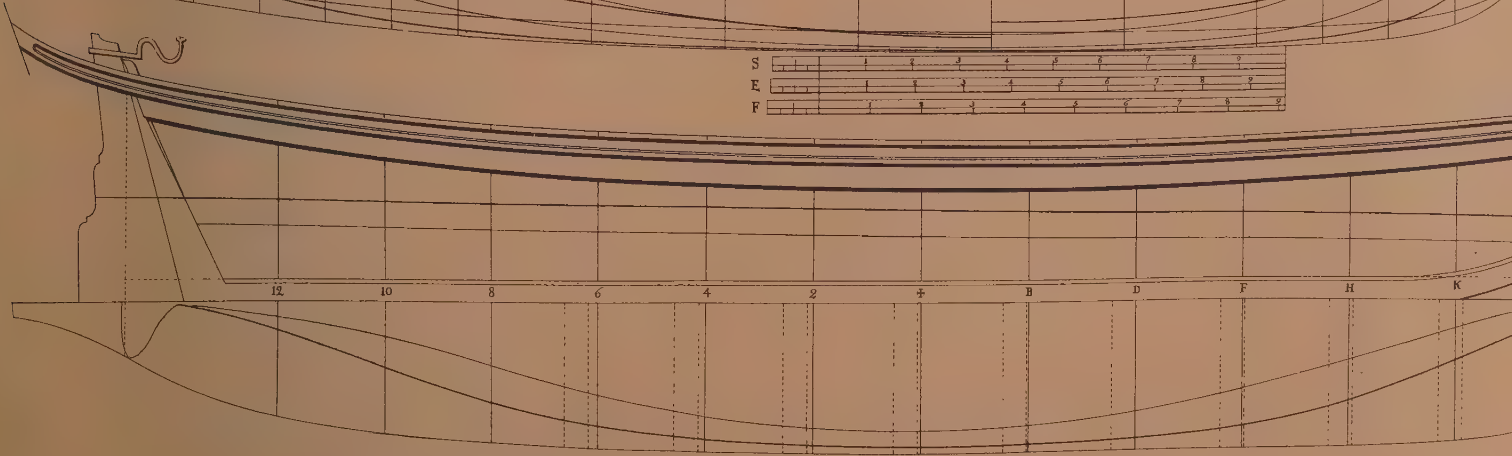


S
E
F
21
18
15
12
9
6

Nº 39



18
15
12
9
6
3
C
F
I



S
E
F
12
10
8
6
4
2
B
D
F
H
K

Pl. XXVII.

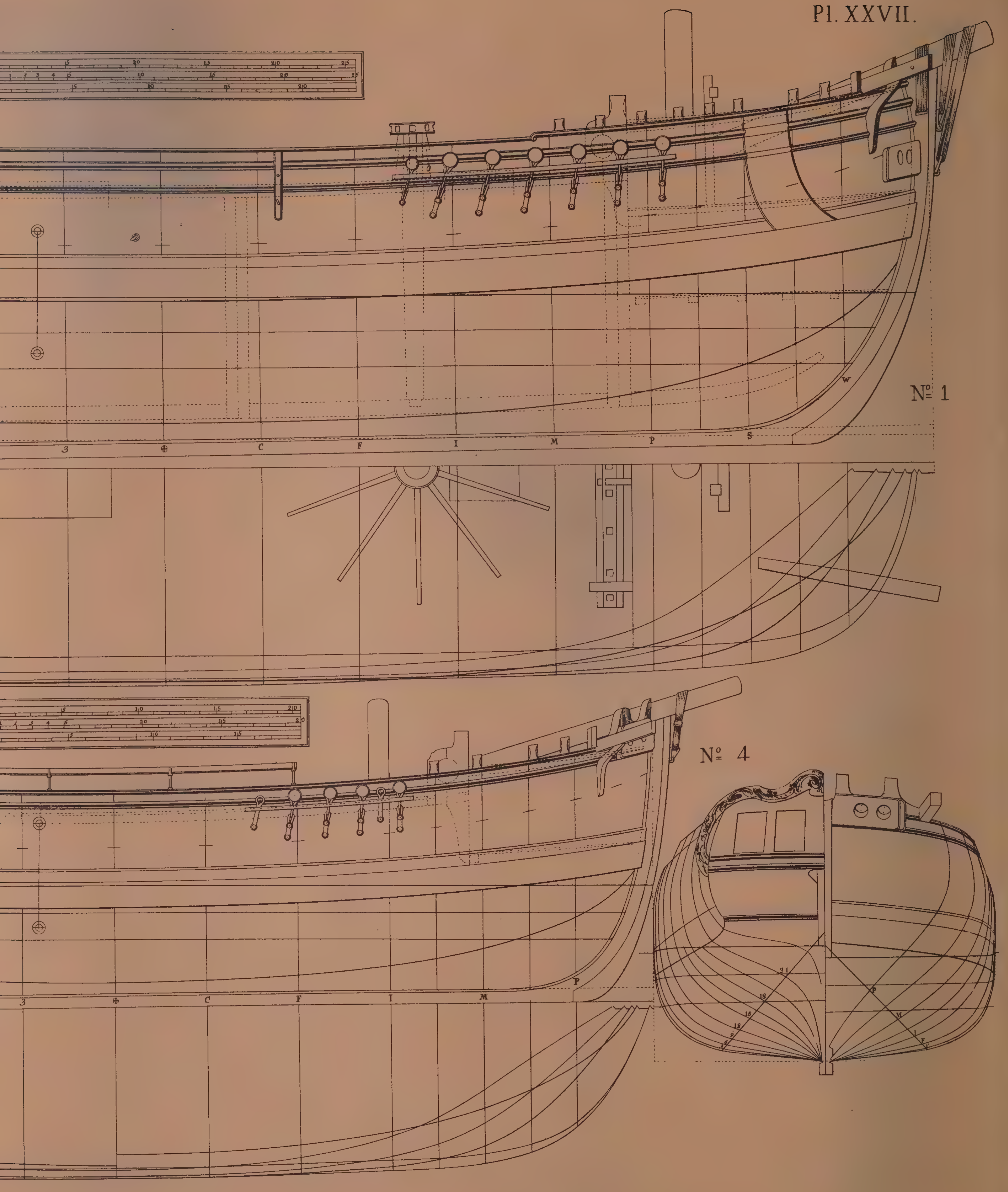


PLATE XXVII

No 1 *Fly-boat or flight*
(Merchant vessels, small draught of water)
with ship's rigging (see plate LXII, No 1)

Length between perpendiculars	132 1/4ft
Breadth moulded	30 1/2ft
Draught as it is on the plan	12ft
Draught laden	14ft 9in
Burthen	292 heavy lasts
Area of the midship frame	278 sqft
Area of the load waterline	3335 sqft
Displacement	25907 cuft
Total cost of construction	26056 krone

Note:

Plate XXVII, No 1 is a single deck fly-boat for transporting timber for masts; there is a capstan near the hatch to the cable tiers for loading the timber.

No 4 *Bark (Merchant vessels, small draught of water)*
with schooner rigging (see plate LXII, No 6)

Length between perpendiculars	82ft
Breadth moulded	22ft
Draught as it is on the plan	8ft 3in
Draught laden	9ft
Burthen	76 heavy lasts
Area of the midship frame	135 sqft
Area of the load waterline	1487 sqft
Displacement	7514 cuft
Total cost of construction	6198 krone

PLATE XXVIII

No 2 *Bark (Merchant vessels, small draught of water)*
with ship's rigging (see plate LXII, No 1)

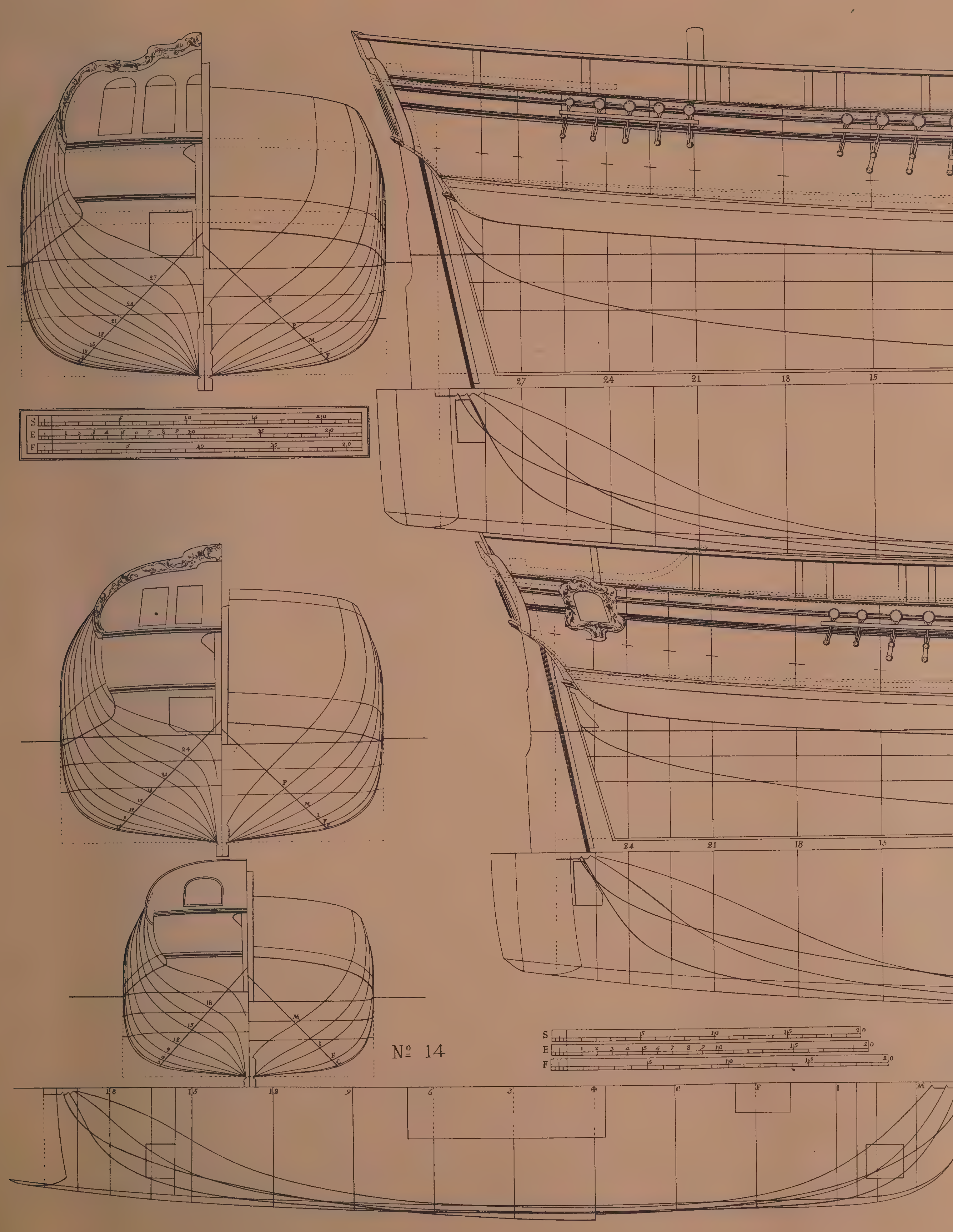
Length between perpendiculars	112ft
Breadth moulded	27ft
Draught as it is on the plan	10ft
Draught laden	12ft 6in
Burthen	191 heavy lasts
Area of the midship frame	199 sqft
Area of the load waterline	2531 sqft
Displacement	15999 cuft
Total cost of construction	16136 krone

No 3 *Bark (Merchant vessels, small draught of water)*
with snow rigging (see Plate LXII, No 2)

Length between perpendiculars	96ft
Breadth moulded	24ft
Draught as it is on the plan	9ft
Draught laden	11ft
Burthen	129 heavy lasts
Area of the midship frame	159 sqft
Area of the load waterline	1898 sqft
Displacement	10415 cuft
Total cost of construction	10287 krone

No 14 *Bark (Merchant vessels, small draught of water)*
With galeass rigging (see plate LXII, No 9)

Length between perpendiculars	64ft
Breadth moulded	171/2ft
Draught as it is on the plan	6ft 6in
Draught laden	7ft 3in
Burthen	33 heavy lasts
Area of the midship frame	83 sqft
Area of the load waterline	897 sqft
Displacement	3579 cuft
Total cost of construction	2563 krone


No 14

Pl. XXIX.

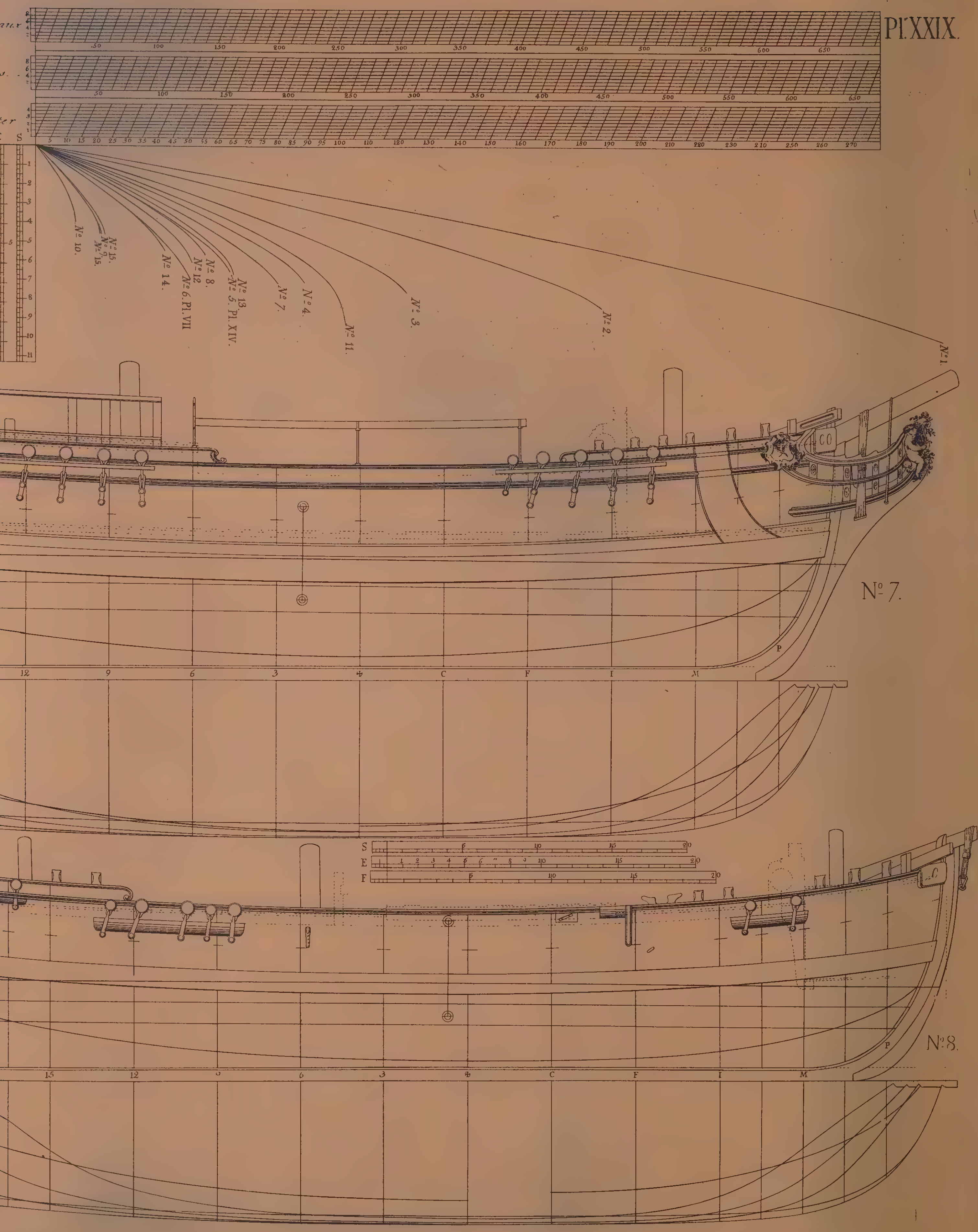


PLATE XXIX

No 7 *Bark (Merchant vessels, small draught of water)*
with brig rigging (see plate LXII, No 4)

Length between perpendiculars	74¼ft
Breadth moulded	21ft
Draught as it is on the plan	8ft 6in
Draught laden	9ft 3in
Burthen	65 heavy lasts
Area of the midship frame	135 sqft
Area of the load waterline	1319 sqft
Displacement	6841 cuft
Total cost of construction	5760 krone

No 8 *Bark (Merchant vessels, small draught of water)*
with kray rigging (see plate LXII, No 10)

Length between perpendiculars	74ft
Breadth moulded	19ft
Draught as it is on the plan	6ft 9in
Draught laden	7ft
Burthen	41 heavy lasts
Area of the midship frame	96 sqft
Area of the load waterline	1150 sqft
Displacement	4721 cuft
Total cost of construction	3723 krone

No 9 *Bark (Merchant vessels, small draught of water)*
with sloop rigging (see plate LXII, No 12)

Length between perpendiculars	46ft
Breadth moulded	15ft
Draught as it is on the plan	5ft 6in
Burthen	13 heavy lasts
Area of the midship frame	60 sqft
Area of the load waterline	555 sqft
Displacement	1773 cuft
Total cost of construction	1321 krone

No 10 *Bark (Merchant vessels, small draught of water)*
with sloop rigging (see plate LXII, No 12)

Length between perpendiculars	38¼ft
Breadth moulded	14ft
Draught as it is in the plan	4ft 9in
Burthen	7½ heavy lasts
Area of the midship frame	43 sqft
Area of the load waterline	428 sqft
Displacement	1060 cuft
Total cost of construction	867 krone

Note:

barks Nos. 9 and 10 are used on Lake Malar

above right:

scale of burthen for merchant vessels with a small draught of water
Plates XXVII,1; XXVIII,2; XXVIII,3; XXVII,4; XIV,5; VII,6; XXIX,7; XXIX,8; XXIX,9; XXIX,10; XXX,11; XXX,12; XXX,13; XXVIII,14; XXX,15
See page 99 for instructions on how to use the scale

PLATE XXX

No 11 *Pink (Merchant vessels, small draught of water)*
with ketch rigging (see plate LXII, No 3)

Length between perpendiculars	80ft
Breadth moulded	26ft
Draught as it is in the plan	11ft
Burthen	63 heavy lasts
Area of the midship frame	213 sqft
Area of the load waterline	1597 sqft
Displacement	8630 cuft
Total cost of construction	7732 krone

Note:

Plate XXX, No 11 is a vessel designed to transport stores such as water, anchors, cordage and ammunition for an armed fleet at war; she also serves for the raising of anchors from the bottom of the sea and must be very stiff, and able to sail well even in storms.

No 12 *Hoy (Merchant vessels, small draught of water)*
with Tjalk rigging (see plate LXII, No 13)

Length between perpendiculars	68ft
Breadth moulded	18ft
Draught as it is in the plan	7ft
Draught laden	7ft 9in
Burthen	44 heavy lasts
Area of the midship frame	97 sqft
Displacement	4360 cuft
Total cost of construction	2091 krone

Note:

No 12 is a Hoy for transporting merchandise for which reason she has a very long hatch with high coamings, the deck on either side being the same height as the rail. Two sorts of frames are drawn. *A* is for shallow waters in which case leeboards would be used. But if frames *B* are used, the leeboards are not needed and she can carry sail well in heavy seas, even in storms. In this case her cargo would be one last less than if frames *A* are used. *C* delineates the deck and after hatch, and *D* the deck and forehatch.

No 13 *Bark (Merchant vessels, small draught of water)*
with galleass rigging (plate LXII, No 9)

Length between perpendiculars	68ft
Breadth moulded	22ft
Draught as it is in the plan	8ft
Burthen	39 heavy lasts
Area of the midship frame	128 sqft
Area of the load waterline	1230 sqft
Displacement	5510 cuft
Total cost of construction	4181 krone

Note:

a vessel with stern loading ports for transporting long timber. The buttock lines can be changed to those shown by the dotted lines for transporting grain in the Baltic, which would result in a better sailer.

No 15 *Lighter (Merchant vessels, small draught of water)*

Length between perpendiculars	50ft
Breadth moulded	14...16ft
Draught as it is in the plan	5ft 6in
Burthen	15 heavy lasts

Note:

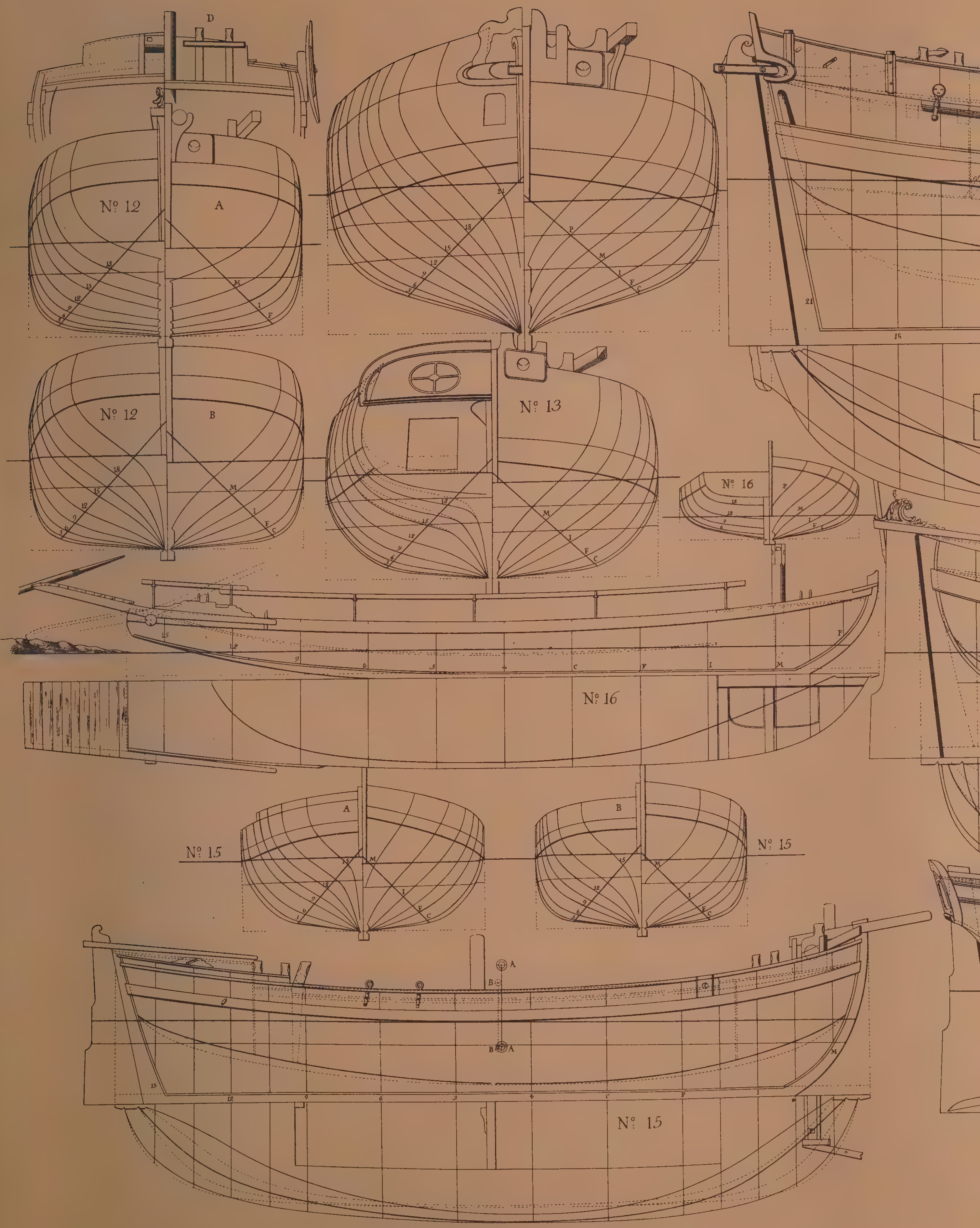
an open vessel.
Profile *A* is for light cargo such as wood for fuel.
Profile *B* is for heavy cargo such as iron, stone.

No 16 *Ferry (Merchant vessels, small draught of water)*

Length between perpendiculars	50ft
Breadth moulded	12ft
Draught as it is in the plan	2ft

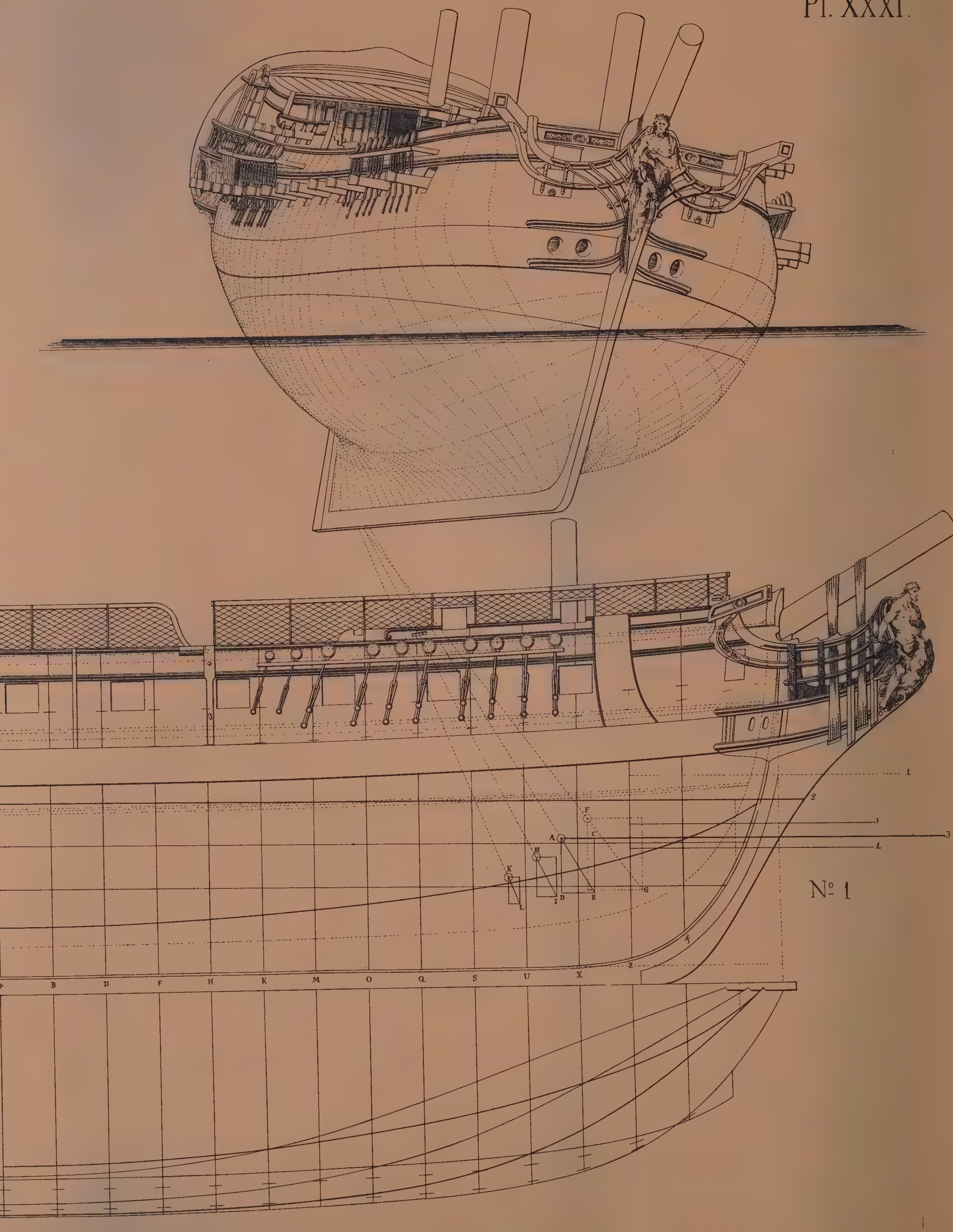
Note:

No 16 is a ferry constructed to transport a large carriage and six horses, and can be used in rough waters. There are four oars and a ramp aft attached to the vessel. In the bows is a small capstan used to pull the carriage aboard. The carriage is transported forward, and the horses further aft.



Nº 12
A
Nº 12
B
Nº 13
Nº 16
Nº 16
A
B
Nº 15
Nº 15
Nº 15

Pl. XXXI.



Nº 1

PLATE XXXI

No 1 *Frigate (Privateers)*

Length between perpendiculars	160ft
Breadth moulded	40 5/6ft
Draught as it is in the plan	18ft 6in
Draught laden	21ft 3in
Burthen	396 heavy lasts
Area of the midship frame	451 sq ft
Area of the load waterline	5021 sq ft
Displacement	46488 cu ft
Guns	40

of which 28 28-pounders of the gun deck
12 6-pounders on the forecastle and quarterdeck

Provisions for 5 months
Water for 2 1/2 months
Number of crew 400 men including officers

Note:

Line *AB* denotes the resistance met with by a plane similar to that of the midship frame when it is propelled at a given velocity through the water. *AC* is the direct resistance at the bow, supposing the velocity to be the same as that of the aforesaid plane; the relative perpendicular resistance is *AD*. From this results the diagonal *EA* which denotes the mean direction of the water resistance when the ship is running before the wind, if it is supposed that it is laden to the load waterline 2 ÷ 2.

If, however, the vessel is so laden that it is immersed to waterline 1, then *FG* is the mean direction of the water resistance.

Similarly *HI* is the mean direction relative to waterline 3 and *KL* is the mean direction when it is supposed that the ship is laden only to waterline 4.

M is the center of gravity of the load waterline and line *MN* is at right angles to it.

PLATE XXXII

Sections and contrivances of the privateer in plate XXXI
Plate XXXII, figure 1 is a section of the privateer frigate supposed to be cut by a plane passing through the middle line of the keel, stem and sternpost.
Figure 2 is a profile section of the same privateer looking forward from the midship frame at the greatest breadth of the vessel.
Figure 3 is a profile section looking aft from the middle of the magazine.
a) keel, b) stem, c) sternpost, d) deadwood, e) knee of the sternpost, f) apron, g) inner false sternpost, h) outer false sternpost, i) rudder, k) gripe, l) knee of the head or cutwater, m) floor-timbers, n) ends of the first futtocks, o) spaces between the frames, p) keelson, q) wing transom, r) lower transom, s) breast hooks, t) counter, u) deck beams, w) bowsprit, x) fore-mast, y) main-mast, z) mizen-mast, A) Orlop deck, B) Lower Deck, C) Upper deck on which are the guns, D) Quarterdeck, E) Forecastle, F) Gangway, G) Poop deck.

Inboard Works of the Ship

Under Orlop Deck A

1 store for meat, salt pork, butter etc, 2 powder store, 3 magazine with racks for filled cartridges, 4 light room.

Under Deck B

5 gunner's store-room, 6 bread-room, 7 ladderway to the magazine, 8 store-room for peas and grain, 9 purser's room, 10 captain's cabin, 11 store for different provisions and the medicine chest, 12 cockpit, 13 pump well, 14 pumps, 15 shot locker, 16 mast steps of fore-mast and main-mast, 17 ballast of old guns, iron blocks, coarse and fine gravel, 18 spirit room, 19 water stowage, 20 stowage for firewood and water casks, 21 cable tiers, 22 boatswain's store-room, 23 store for spare blocks, 24 sail room, 25 coal for cooking stoves, 26 loose shot to be stowed as ballast where needed to trim the ship, 27 pillars in the hold, 28 spare anchor.

On Deck B

29 hatchway to the light room, 30 hatchway to the magazine, 31 mast step for the mizen-mast, 32 hatchway to the provision rooms, 33 hatch and ladderway to the pump well, 34 hatch and ladderway to the shot locker, 35 large hatch and ladderway to the water store, 36 fore-hatch and ladderway to the cable tiers, 37 hatch and ladderway to the sail room, 38 hatchway to the coals.

Between Decks B and C

39 gun-room, 40 tiller, 41 officer's bed places, 42 main capstan for raising the anchor, 43 upper part of the pumps, 44 cable bitts, 45 cross-piece of the cable bitts, 46 manger, 47 hawse-holes.

On Gun Deck C

48 ladderway from the quarterdeck to the gun-room, 49 great cabin, 50 officers' dining table, 51 gallery door, 52 bed places for two officers made of sailcloth, 53 block for the rudder tackle, 54 sheaves through which the tiller ropes run to the wheel, 55 water beakers, 56 drumhead of the capstan, 57 main topsail sheet bitts, 58 gun ports, 59 bow gun ports, 60 kevels for belaying, 61 crew's galley, 62 officers' galley, 63 ring bolts for the forecourse yard braces, 64 pillars under the waist, 65 pillars under the forecastle and between decks, 66 capstan bars.

On the Quarterdeck D

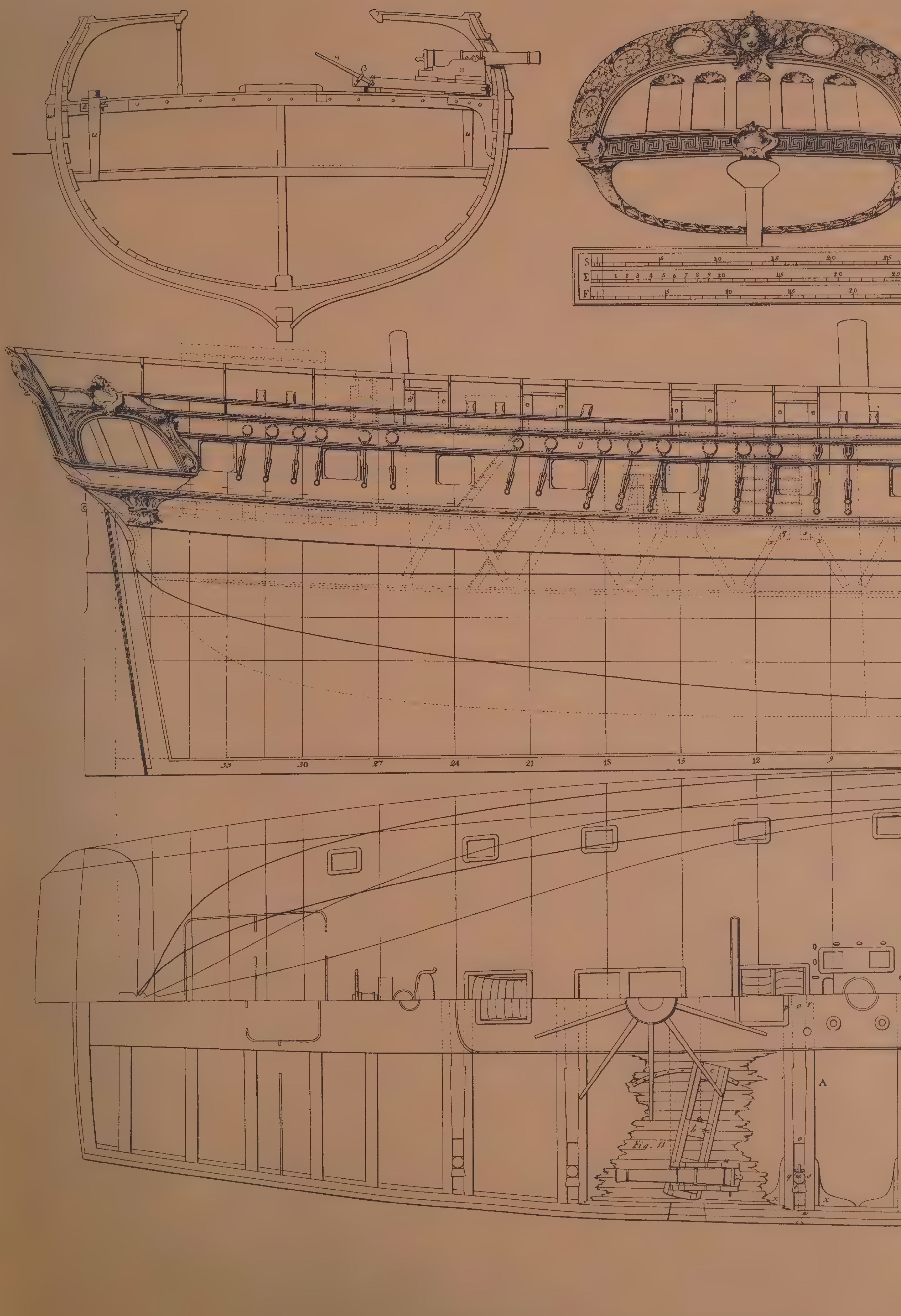
67 gallery, 68 captain's cabin, 69 gallery door, 70 cabins for officers, 71 wheel, 72 companion of the ladderway to the great cabin, 73 after hatch, 74 hatches to the pumps, 75 timber-heads.

On the Forecastle E, Gangway F and Poop G

76 manrope on the inboard side of the gangway, 77 gratings in the gangway, 78 ladderway to the gun deck, 79 ship's bell, 80 fore jear capstan, 81 hatchway to the forecastle, 82 timber-heads for the fore topsail sheet, 83 cat-head, 84 rails of the head, 85 taffrail or taffarell, 86 quarter pieces, 87 hatches, with gratings, 88 gallery, 89 deck beams, 90 ladderways, 91 provisioning hatch.

Figures 2 and 3

92 floors, 93 2nd futtock, 94 4th futtock, 95 1st futtock, 96 3rd futtock, 97 ceiling, 98 shelf, 99 waterway, 100 spirketting, 101 hanging knees, 102 planking, 103 main wale, 104 bulwark.



u
u
S 5 10 15 20 25
E 1 2 3 4 5 6 7 8 9 10 15 20 25
F 5 10 15 20
33
30
27
24
21
18
15
12
9
A
Fig. 11

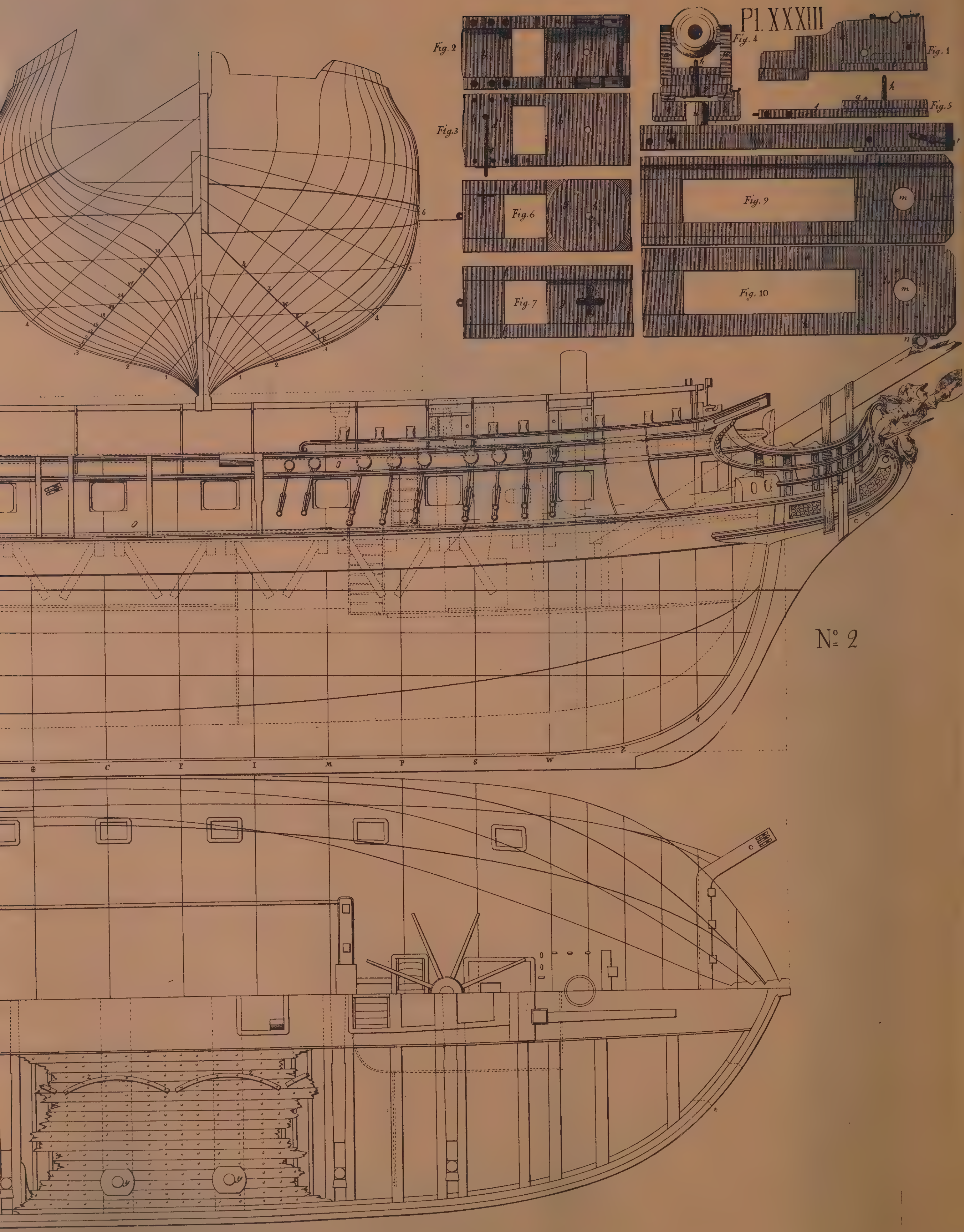

Pl. XXXIII
Fig. 1
Fig. 2
Fig. 3
Fig. 4
Fig. 5
Fig. 6
Fig. 7
Fig. 9
Fig. 10
N° 2

PLATE XXXIII

No. 2 *Frigate (Privateers)*

Length between perpendiculars	150ft
Breadth moulded	39ft
Draught as it is on the plan	17ft 6in
Draught laden	19ft
Burthen	290 heavy lasts
Area of the midship frame	411 sqft
Area of the load waterline	4613 sqft
Displacement	39828 cuft
Guns	38

of which 26 18-pounders on the gun deck
12 6-pounders on the forecastle and quarterdeck

Provisions for 5 months
Water for 21/2 months
Number of crew 360 men including officers.

Note:

Plate XXXIII, figures 1, 2, 3, etc. are draughts of a new sort of gun carriage, made principally of three main parts as shown in figure 11. a) the carriage itself, b) the lower portion with an iron pivot so that the carriage may be turned and c) the movable wooden slide along which the carriage can recoil.

Figure 1 is the side view of the carriage: a) the cheek-plates of the gun carriage, b) the cross-piece, c) the hole through which the breeching tackle passes.

Figure 2 is the carriage from above. The gun is to be imagined resting on this, secured by the trunnion plates.

Figure 3 is the carriage from below. d) is a spring latch with a notch at e).

Figure 4 is the end view of the slide, the wooden base plate and the gun mounted in the carriage.

Figure 5 is the side view of the base plate.

Figure 6 is the view from above and figure 7 the view from below the base plate. f) are the two side pieces: g) a piece of timber placed transversely on which the carriage rests when it is turned: h) a large iron pivot which passes through the carriage and holds it fast to the transverse piece g): i) an iron rack in which latch d) engages when the carriage lies exactly over the base plate.

Figure 8 is the side view of the wooden slide which is figure 9 is seen from above and in figure 10 from below. k) are the side pieces: l) is a bed of thin planks: m) is the hole through which the bollard passes: n) is an iron ring on the side of the slide to which the breeching tackle may be made fast.

It is necessary with carriages such as this that the beams be made of several parts jointed together.

A) is a beam made of five parts: oo) the center part of which only half is drawn; on either side are two arms pq) and rs) which are jointed to the center part at their inner ends and are spaced apart at the outer. t) is a block let into these arms which holds bollard u). A heavy forged bolt w) penetrates the side of the ship as well as the bollard and block t); the bollard itself is so long that it may be bolted to the lowest deck. x) are knees and y) a piece of timber on deck on which the outer end of the slide rests. z) are traverse rails on which the end of the slide is moved when the guns are trained. This is done by means of a capstan bar passed through the eyes $\beta\beta$ in the end of the slide.

When these carriages are constructed it is necessary to be sure that the pivot on the base plate which passes through the bed is placed exactly under the center of gravity of the gun mounted in the carriage relative to their length; equally the center of gravity of the gun carriage with the base plate must be a little inboard of the bollard, far enough inboard so that the center of gravity will not pass over the middle of the bollard when the vessel is inclined and the guns lie to leeward.

With such a carriage one man alone is able to aim an 18-pounder very quickly and easily. That is to say that in the same length of time he could fire almost twice as often as when using the same gun mounted in the usual way. These gun carriages can also be lashed down better, both athwart the ship and fore-and-aft.

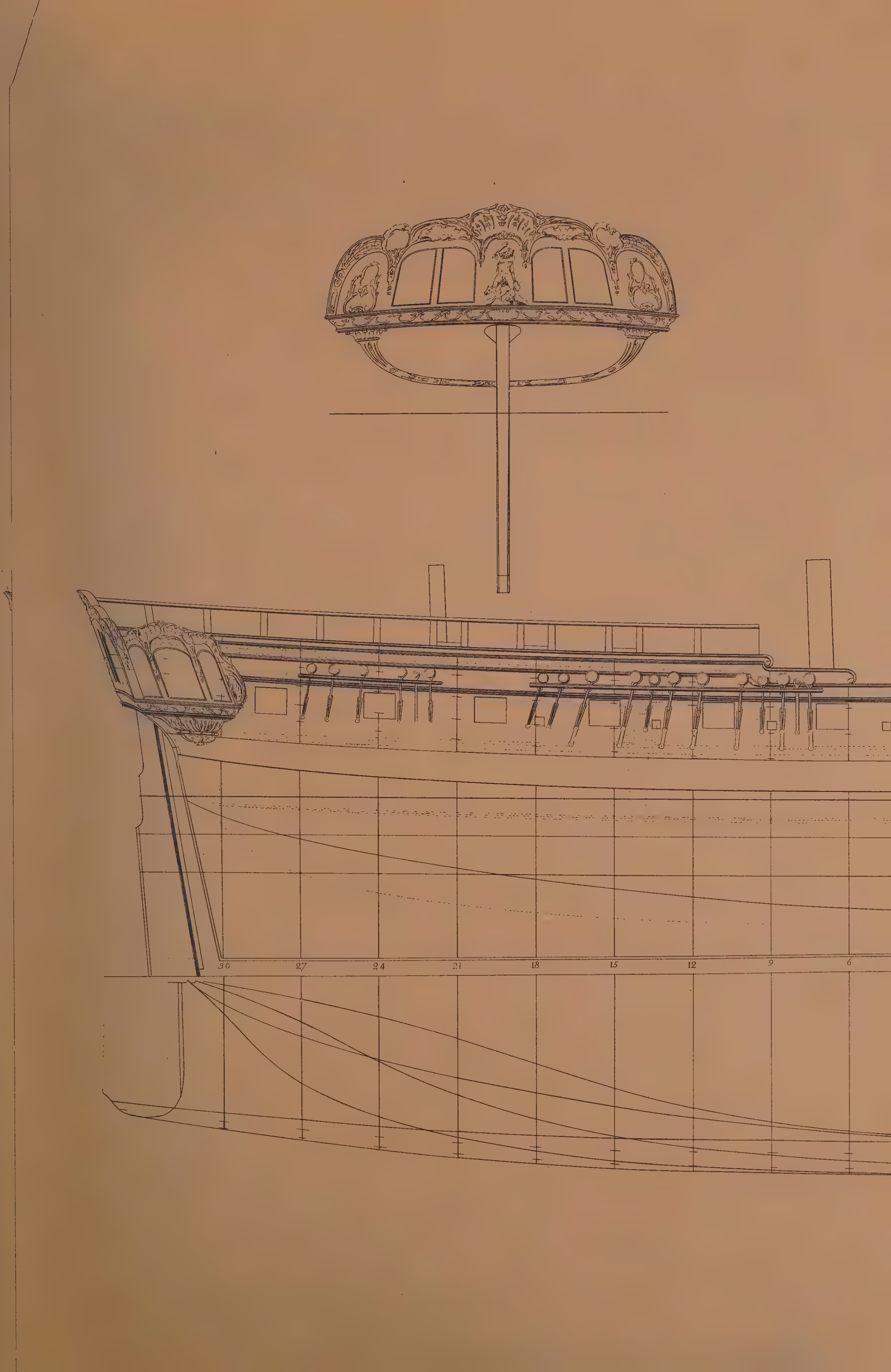
PLATE XXXIV

No 3 *Frigate (Privateers)*

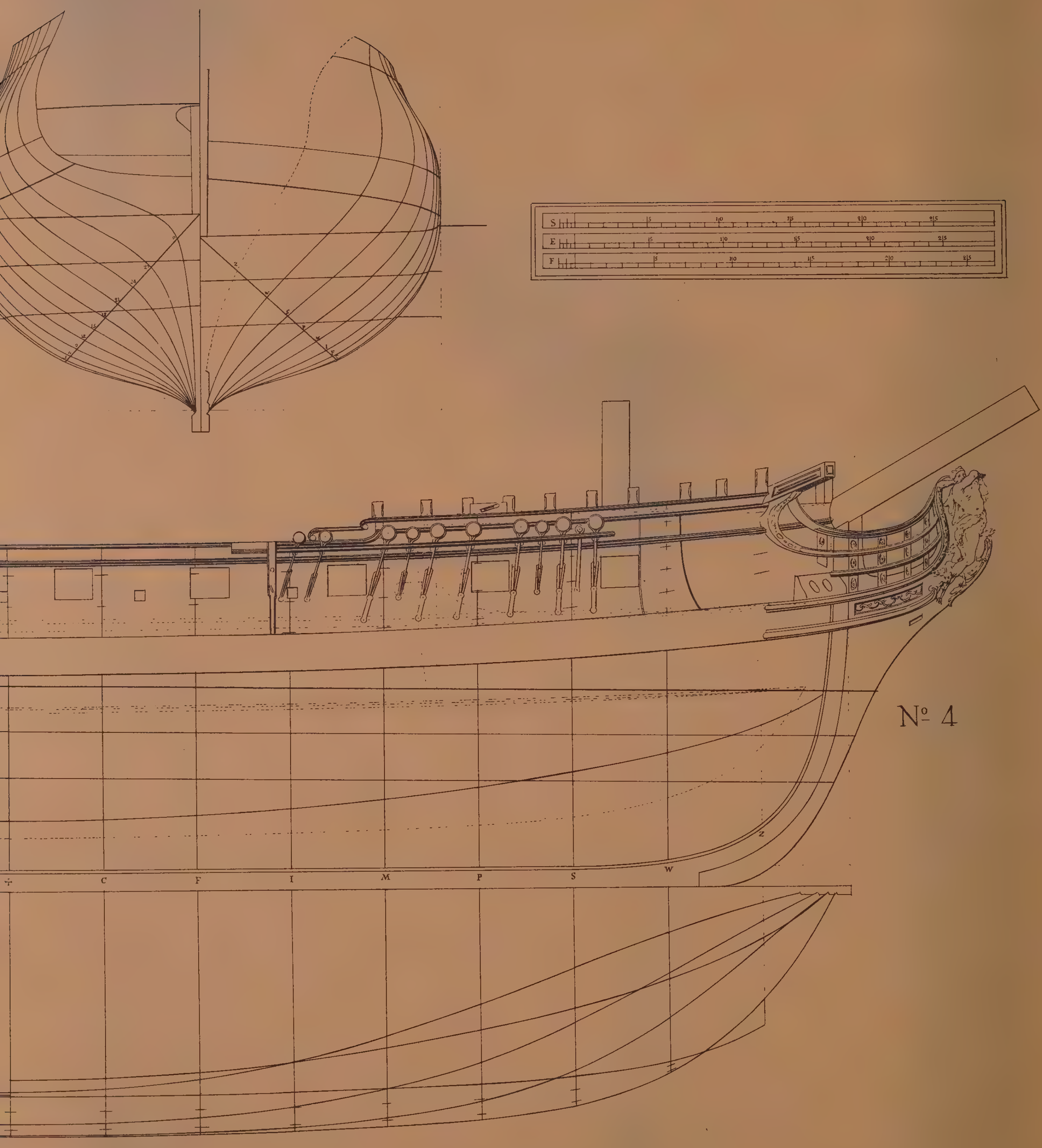
Length between perpendiculars	138ft
Breadth moulded	35 1/2ft
Draught as it is in the plan	16ft
Draught laden	17ft 9in
Burthen	233 heavy lasts
Area of the midship frame	342 sq ft
Area of the load waterline	3803 sq ft
Displacement	29412 cu ft
Guns	34

of which 24 12-pounders are on the gun deck
10 4-pounders on the forecastle and quarterdeck

Provisions for 4 1/2 months
Water for 2 1/2 months
Number of crew 310 men including officers.


30
27
24
21
18
15
12
9
6

Pl. XXXV.



Nº 4

PLATE XXXV

No 4 *Frigate (Privateers)*

Length between perpendiculars	128 1/2ft
Breadth moulded	33 3/4ft
Draught as it is in the plan	15ft
Draught laden	16ft 9in
Burthen	196 heavy lasts
Area of the midship frame	298 sq ft
Area of the load waterline	3279 sq ft
Displacement	24023 cu ft
Guns	32

of which 24 8-pounders are on the gun deck
8 3-pounders on the quarter-deck and forecastle

Pairs of oars	7
Provisions for	4 1/2 months
water for	2 1/2 months

Number of crew 260 men including officers

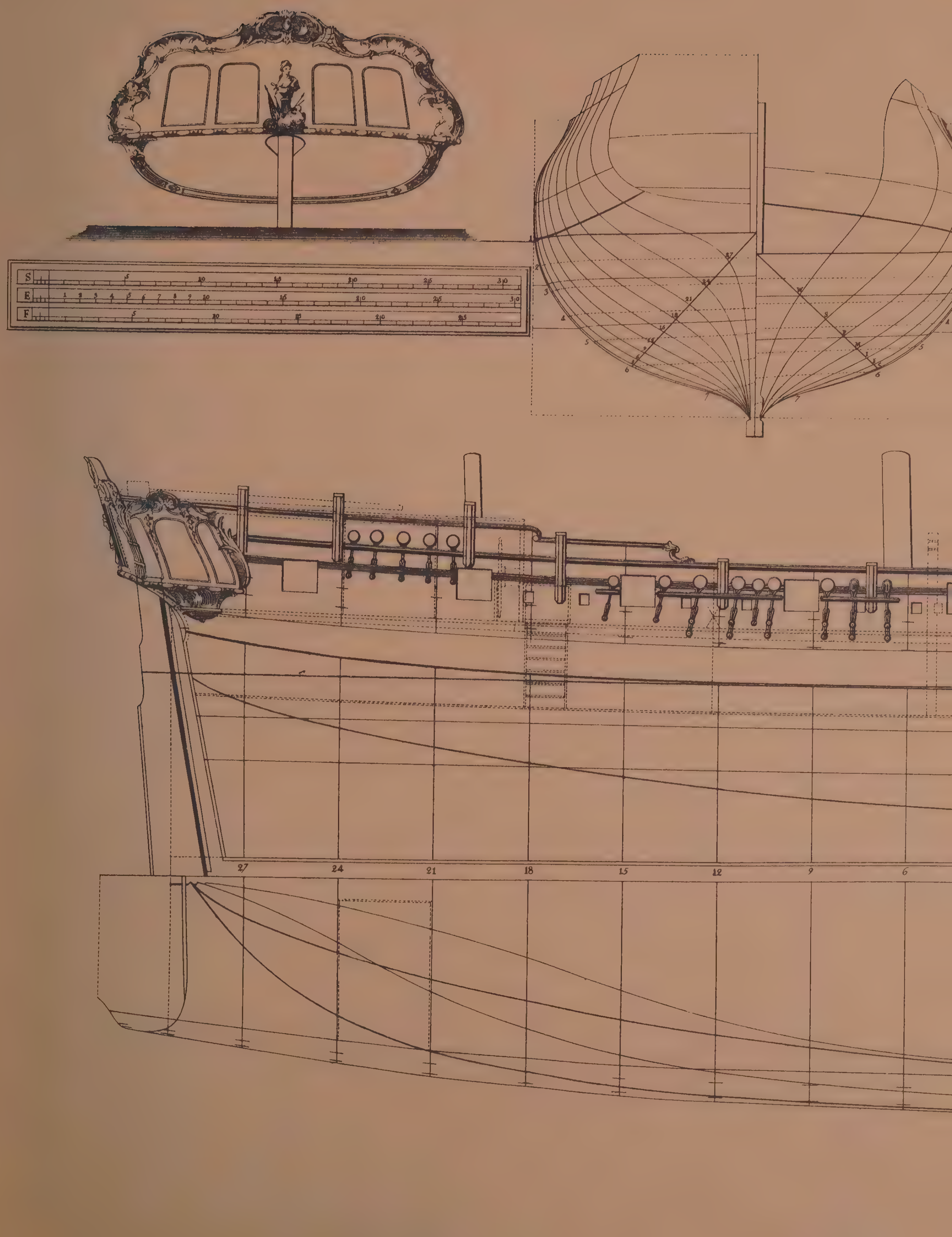
PLATE XXXVI

No 5 *Frigate (Privateers)*

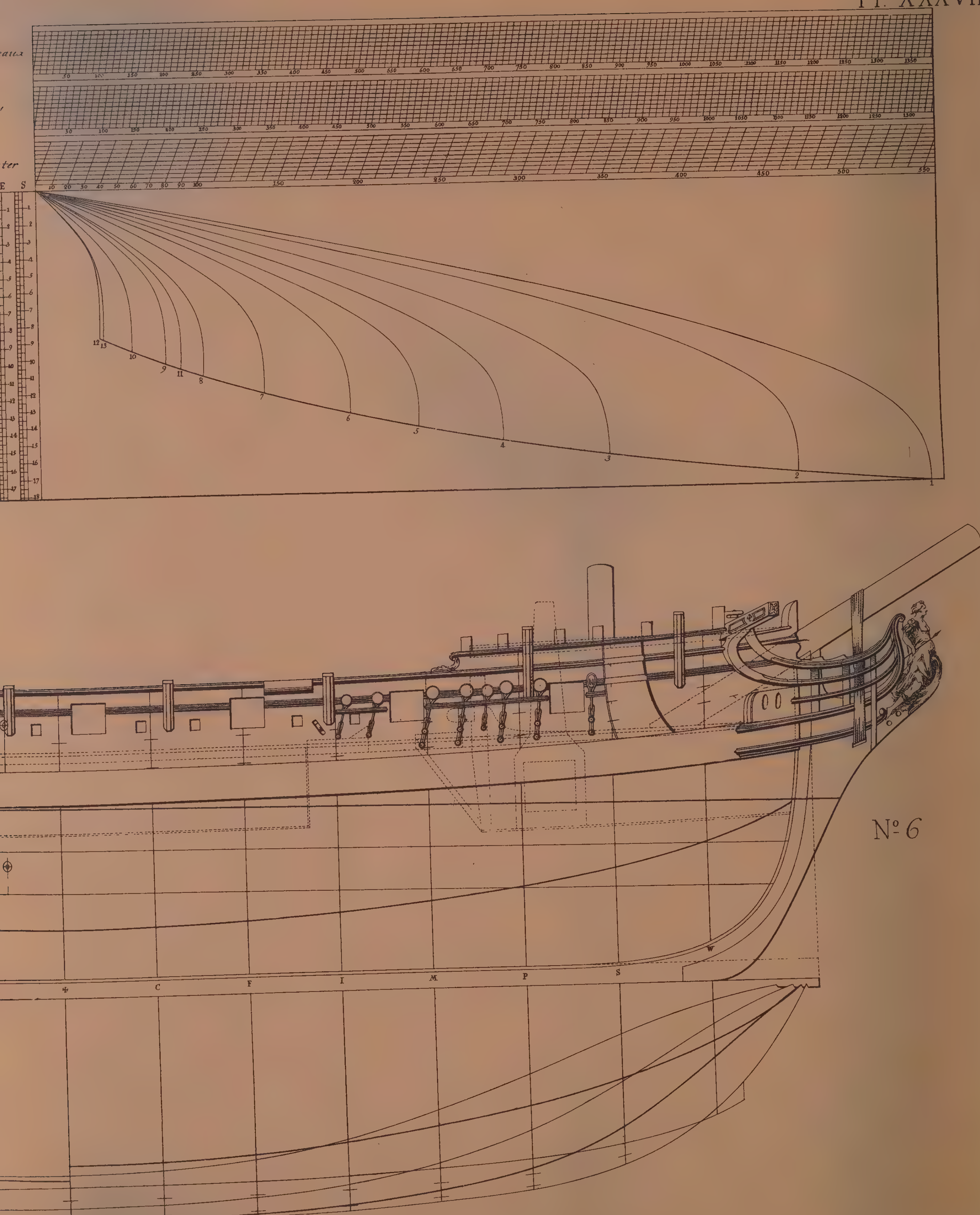
Length between perpendiculars	120ft
Breadth moulded	31 1/2ft
Draught as it is in the plan	14ft 8in
Draught laden	16ft 2in
Burthen	161 heavy lasts
Area of the midship frame	264 sqft
Area of the load waterline	2904 sqft
Displacement	20000 cuft
Guns	22
of which 20 6-pounders on the gun deck	
2 4-pounders on the forecastle and quarterdeck	
Swivel guns	32 3-pounders
Pairs of oars	7
Provisions for	4 months
Water for	2 months
Number of crew	220 men including officers.

Plate XXXVI, figures 1, 2, 3, 4 and 5 are draughts of a carriage for the swivel guns in this vessel.
Figure 1 is the side view of the carriage, a) the side cheeks and b) the bed.
Figure 2 is a view of the bed from below.
Figure 3. A wooden block extends beyond the bulwarks and is fastened both there and at the inner end d) by an iron plate c): at the inner end d) is a vertical support of timber which stands on the deck.
Figure 4 shows the upper and figure 5 the lower side of this block on which the carriage stands and to which it is held fast by an iron bolt on which the gun swivels.
Figures 6, 7 and 8 show the whole assembled together.
The gun bollards, beams and the gun carriages in this ship are constructed in the same manner as is shown for privateer No 2, but in place of the knees the outer ends of the beams are supported by long clamps ff) which are fastened to the ceiling and under the beams, as well as by blocks gg) which are let into the under side of the beams and bolted—as is to be seen on the draughts at *A* and *B*. hh) are two ribbands which run parallel to the center line of the ship over the frames. ii) are two ribbands which run exactly over the aforementioned pieces, under the beams and at right angles to them. kk) are riders which are scored above and below upon the longship timbers aforementioned. ll) are braces which are scored upon the riders kk). m) wedges to effectuate the whole. pp) is an iron plate which passes over the beams, whose ends are riveted fast to two riders jointed together, so that the tenons on the braces cannot work loose from the riders. The whole bracing is so planned that the ship cannot sag amidships. For this to happen the angles ikk) would have to increase, which they cannot do because the diagonals ll) are so fixed as to remain always the same length. This method is of great use for long light vessels. The construction would be the same as for gun carriages, and from experience is fully justifiable. n) are small openings with gratings over them to allow the smoke of the guns to blow away. o) is a hatch to the galley.

above right:
Ketch No 9 of Plate XXXIX in frame



S
E
F
27
24
21
18
15
12
9
6



Nº 6

PLATE XXXVII

No 6 *Frigate (Privateers)*

Length between perpendiculars		112ft
Breadth moulded		30ft
Draught as it is in the plan		13ft 3in
Draught laden		14ft 9in
Burthen		135 heavy lasts
Area of the midship frame		228 sqft
Area of the load waterline		2587 sqft
Displacement		16210 cuft
Guns	18	6-pounders on the gun deck
Swivel guns	22	3-pounders
Pairs of oars	12	
Provision for	4 months	
Water for	2 months	

Number of crew 200 men including officers

above right:

scale of burthen for Privateers:
Plates XXXI,1; XXXIII,2; XXXIV,3; XXXV,4; XXXVI,5; XXXVII,6; XXXVIII,7; XXXVIII,8; XXXIX,9; XXXIX,10; XL,11; XL,12; XL,13.
See page 99 for instructions on how to use this scale.

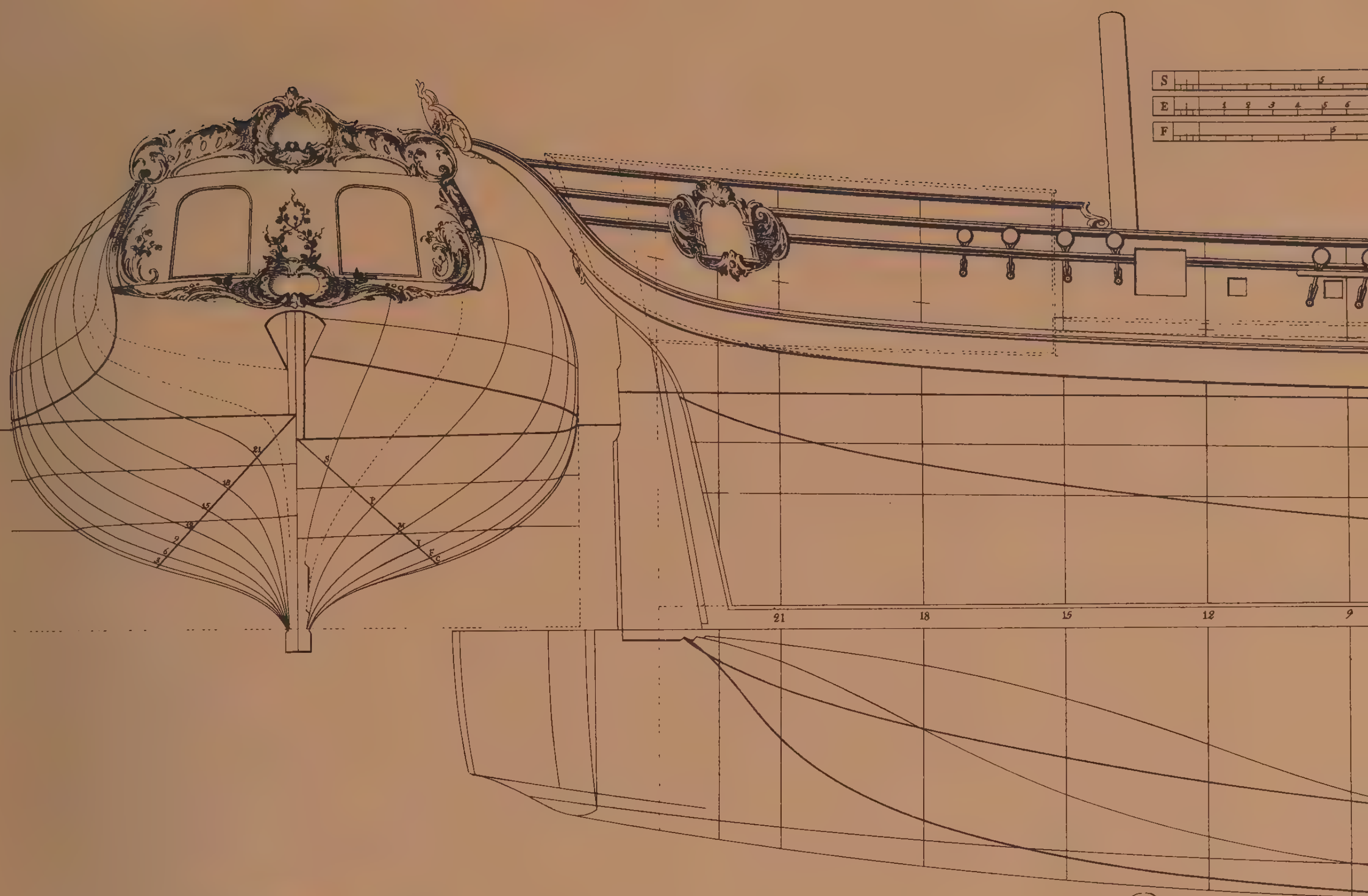
PLATE XXXVIII

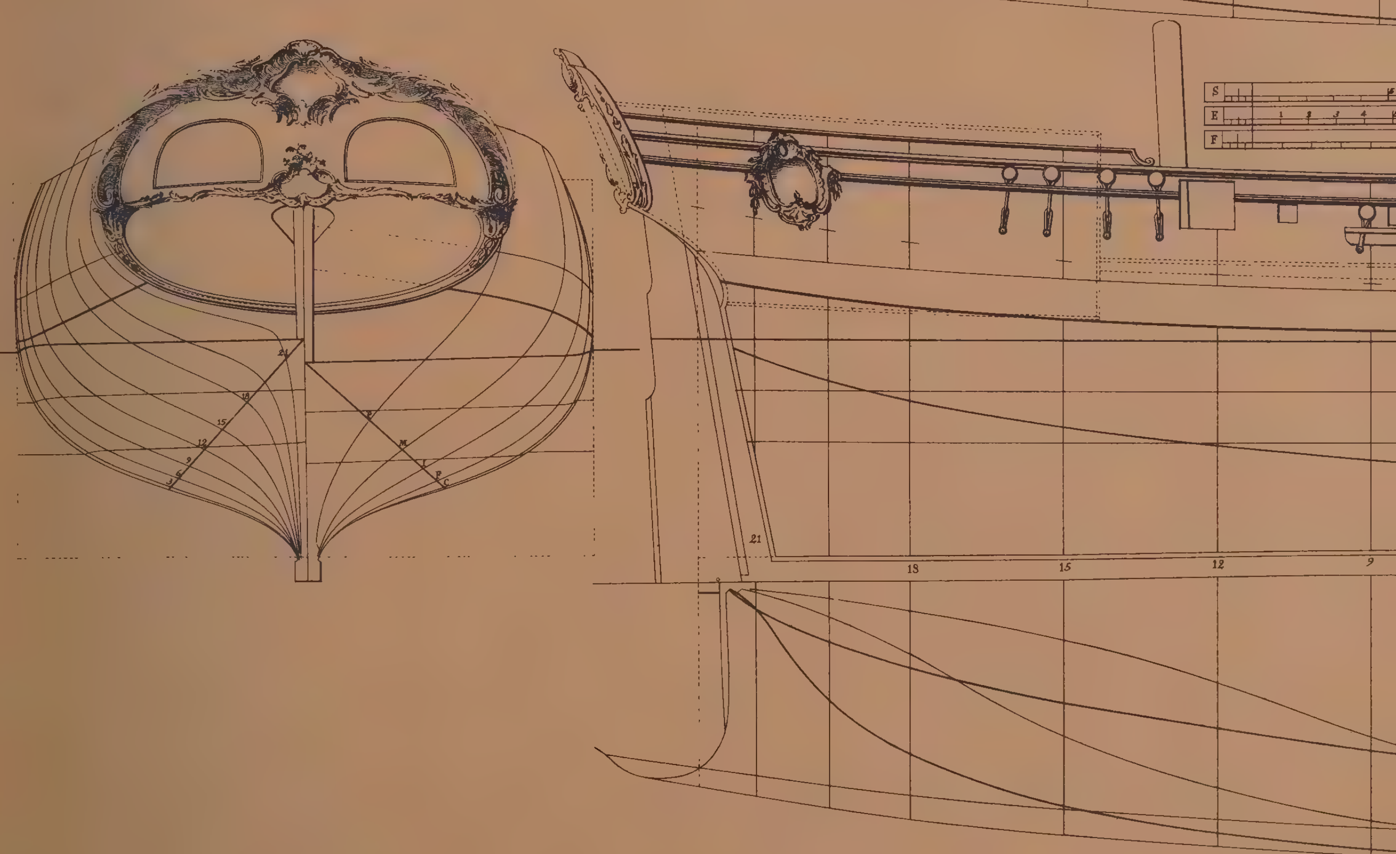
No 7 *Frigate (Privateers)*

Length between perpendiculars	103ft
Breadth moulded	27 1/2ft
Draught as it is in the plan	11ft 6in
Draught laden	12ft 9in
Burthen	96 heavy lasts
Area of the midship frame	180 sqft
Area of the load waterline	2171 sqft
Displacement	11674 cuft
Guns	16 6-pounders on the gun deck
Pairs of oars	11
Provisions for	3 months
Water for	1 1/2 months
Number of crew	160 men including officers

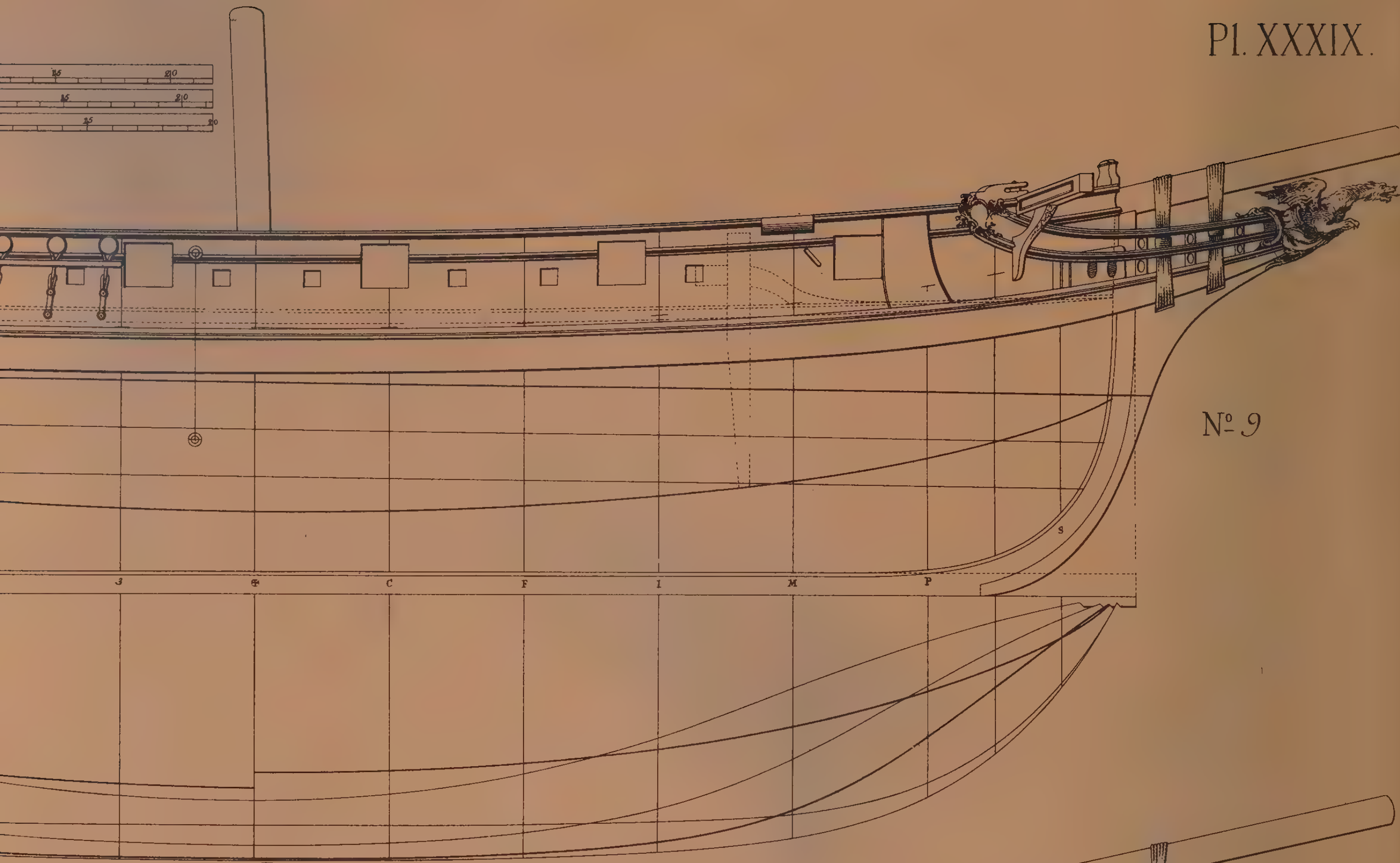
No 8 *Snow (Privateers)*

Length between perpendiculars	93ft
Breadth moulded	25ft
Draught as it is in the plan	10ft 6in
Draught laden	11ft 9in
Burthen	74 heavy lasts
Area of the midship frame	147 sqft
Area of the load waterline	1752 sqft
Displacement	8502 cuft
Guns	14 4-pounders on the gun deck
Swivel guns	12 3-pounders
Pairs of oars	10
Provision for	3 months
Water for	1 1/2 months
Number of crew	115 men including officers

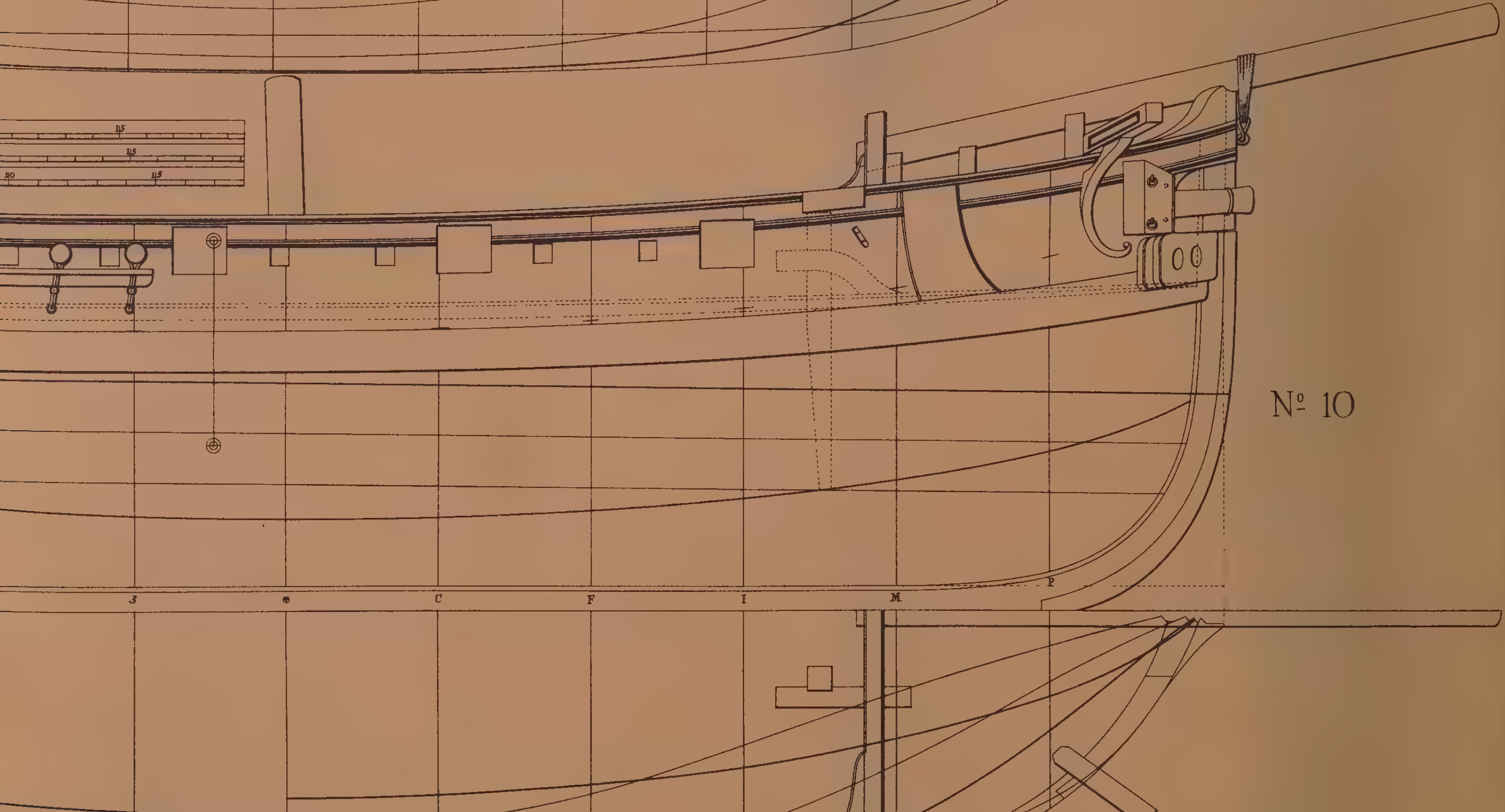

S
E
F
21
18
15
12
9


S
E
F
21
18
15
12
9

Pl. XXXIX.



№ 9



№ 10

PLATE XXXIX

No 9 *Ketch (Privateers)*

Length between perpendiculars	85ft
Breadth moulded	23ft
Draught as it is in the plan	9ft 8in
Draught laden	10ft 8in
Burthen	54 heavy lasts
Area of the midship frame	124 sqft
Area of the load waterline	1497 sqft
Displacement	6572 cuft
Guns	12 4-pounders on the gun deck
Pairs of oars	9
Provisions for	21/2 months
Water for	11/4 months
Number of crew	90 men including officers.

No 10 *Ketch (Privateers)*

Length between perpendiculars	76ft
Breadth moulded	21ft
Draught as it is in the plan	8ft 9in
Draught laden	9ft 9in
Burthen	42 heavy lasts
Area of the midship frame	99 sqft
Area of the load waterline	1226 sqft
Displacement	4786 cuft
Guns	11
of which	10 3-pounder on the gun deck
	1 18-pounder on the quarter-deck
Pairs of oars	8
Provisions for	2 months
Water for	1 month
Number of crew	70 men including officers

PLATE XL

Note:

Plate XL, figures 1 and 2 are drawings of a crotch made of wood for swivel guns; using such a crotch the guns can be trained and fired as exactly as if the swivel guns were mounted in a carriage, which is seldom the case for they usually stand in an iron crotch.

Figure 3 shows how the cylindrical pivot at the lower end of the crotch rests in the sockets in the wooden frame which is bolted to the side of the ship.

No 11 *Schooner (Privateers)*

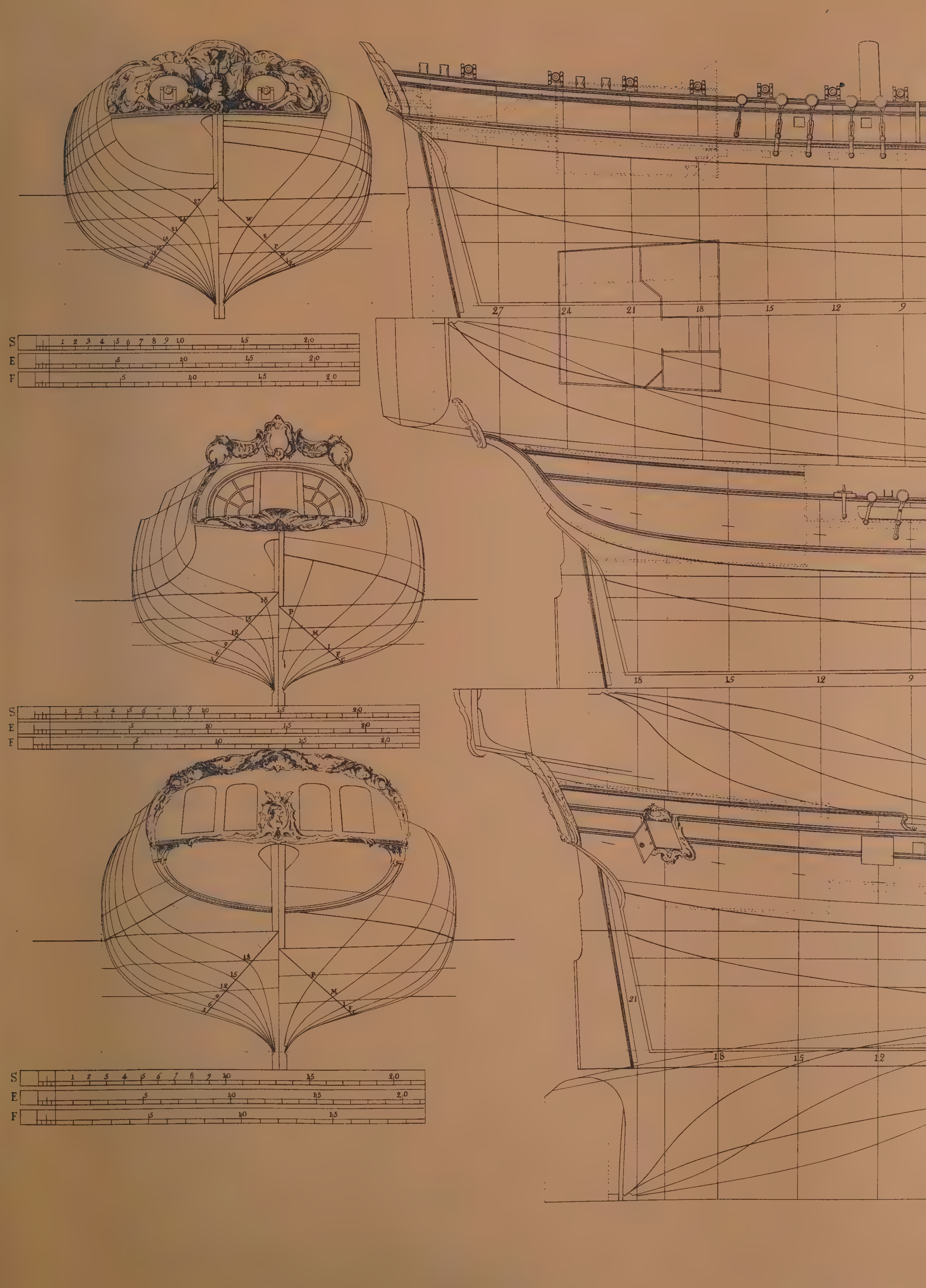
Length between perpendiculars	96ft
Breadth moulded	23 3/4ft
Draught as it is in the plan	10ft
Draught laden	11ft
Burthen	66 heavy lasts
Area of the midship frame	123 sqft
Area of the load waterline	1675 sqft
Displacement	7400 cuft
Guns	2 6-pounders on the quarterdeck
Swivel guns	32 3-pounders
Pairs of oars	10
Provisions for	2 months
Water for	1 month
Number of crew	100 men including officers

No 12 *Schooner (Privateers)*

Length between perpendiculars	72ft
Breadth moulded	19ft
Draugh as it is in the plan	7ft 4in
Draught laden	8ft 1in
Burthen	27 heavy lasts
Area of the midship frame	72 sqft
Area of the load waterline	991 sqft
Displacement	3088 cuft
Guns	2 4-pounders on the quarterdeck
Swivel guns	10 3-pounders
Pairs of oars	8
Provisions for	2 months
Water for	1 month
Number of crew	50 men including officers

No 13 *Sloop (Privateers)*

Length between perpendiculars	64ft
Breadth moulded	21ft
Depth in hold	8ft
Draught laden	9ft
Burthen	30 heavy lasts
Area of the midship frame	82 sqft
Area of the load waterline	995 sqft
Displacement	3272 cuft
Guns	10
of which	8 3-pounders on the gun deck
	2 6-pounders on the quarterdeck
Pairs of oars	7
Provisions for	2 months
Water for	1 month
Number of crew	50 men including officers


S
E
F
27
24
21
18
15
12
9

Pl. XLI.

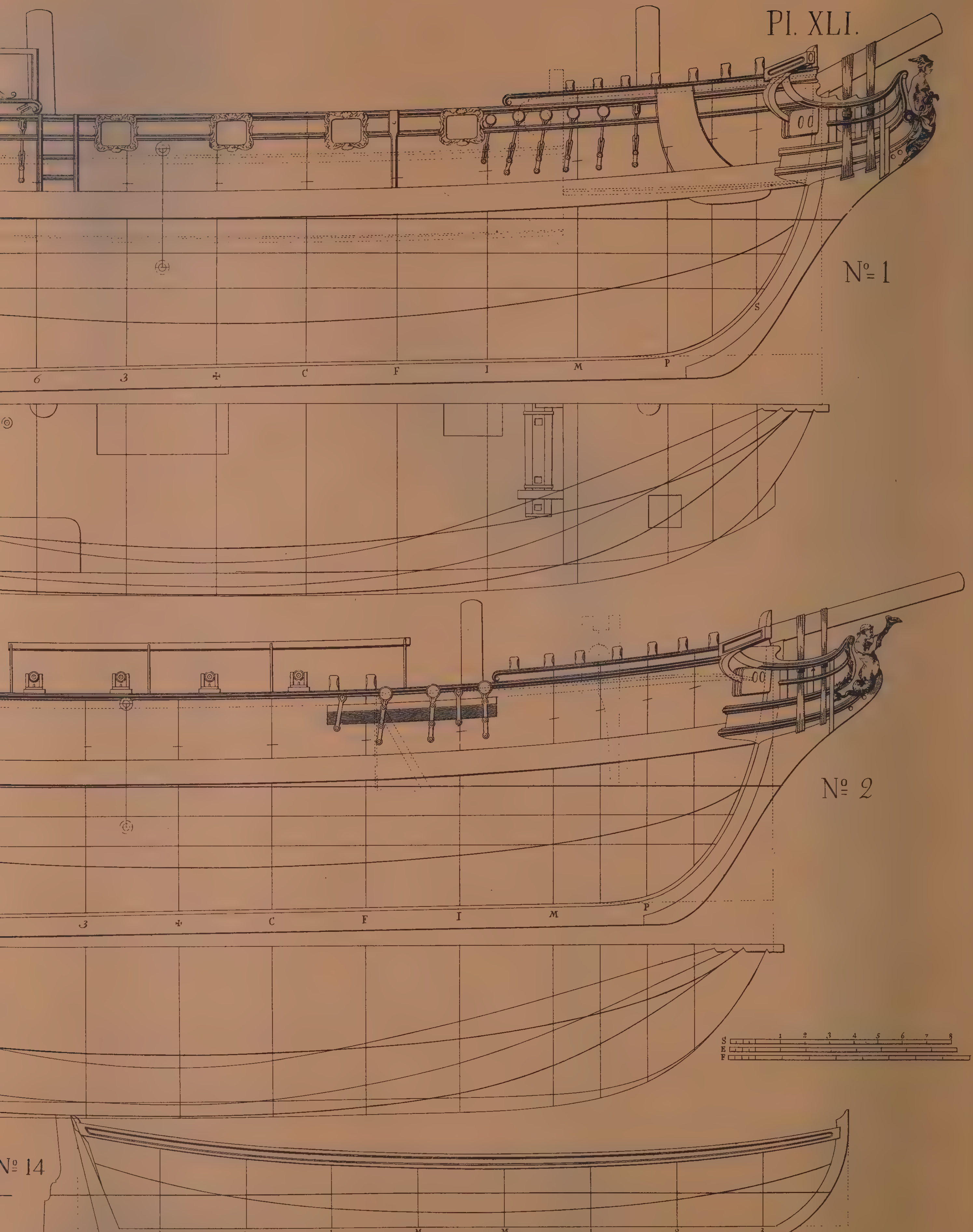


PLATE XLI

No 1 *Frigate (Packet boats)*

Length between perpendiculars	83 3/4ft
Breadth moulded	23 1/6ft
Draught as it is in the plan	11ft
Draught laden	11ft 9in
Burthen	55 heavy lasts
Displacement	7122 cu ft

No 2 *Schooner (Packet boats)*

Length between perpendiculars	75 5/6ft
Breadth moulded	19ft
Draught as it is in the plan	8ft 9in
Draught laden	9ft 3in
Burthen	28 heavy lasts
Displacement	3517 cu ft

No 14 *A French Pinnace of 6 oars*
(Different sorts of smaller vessels)

Length between perpendiculars	31 1/2ft
Breadth moulded	7 7/12ft
Pairs of oars	6

PLATE XLII

No 3 *Sloop with greater or lesser draught of water (Packet boats)*

Length between perpendiculars	62ft
Breadth moulded	18ft
Draught as it is in the plan (greater)	8ft 4in
Draught as it is in the plan (lesser)	6ft
Draught laden (greater)	8ft 10in
Draught laden (lesser)	6ft 6in
Burthen (greater)	23 heavy lasts
Burthen (lesser)	20 heavy lasts
Displacement (greater)	2952 cu ft
Displacement (lesser)	2598 cu ft

Note:

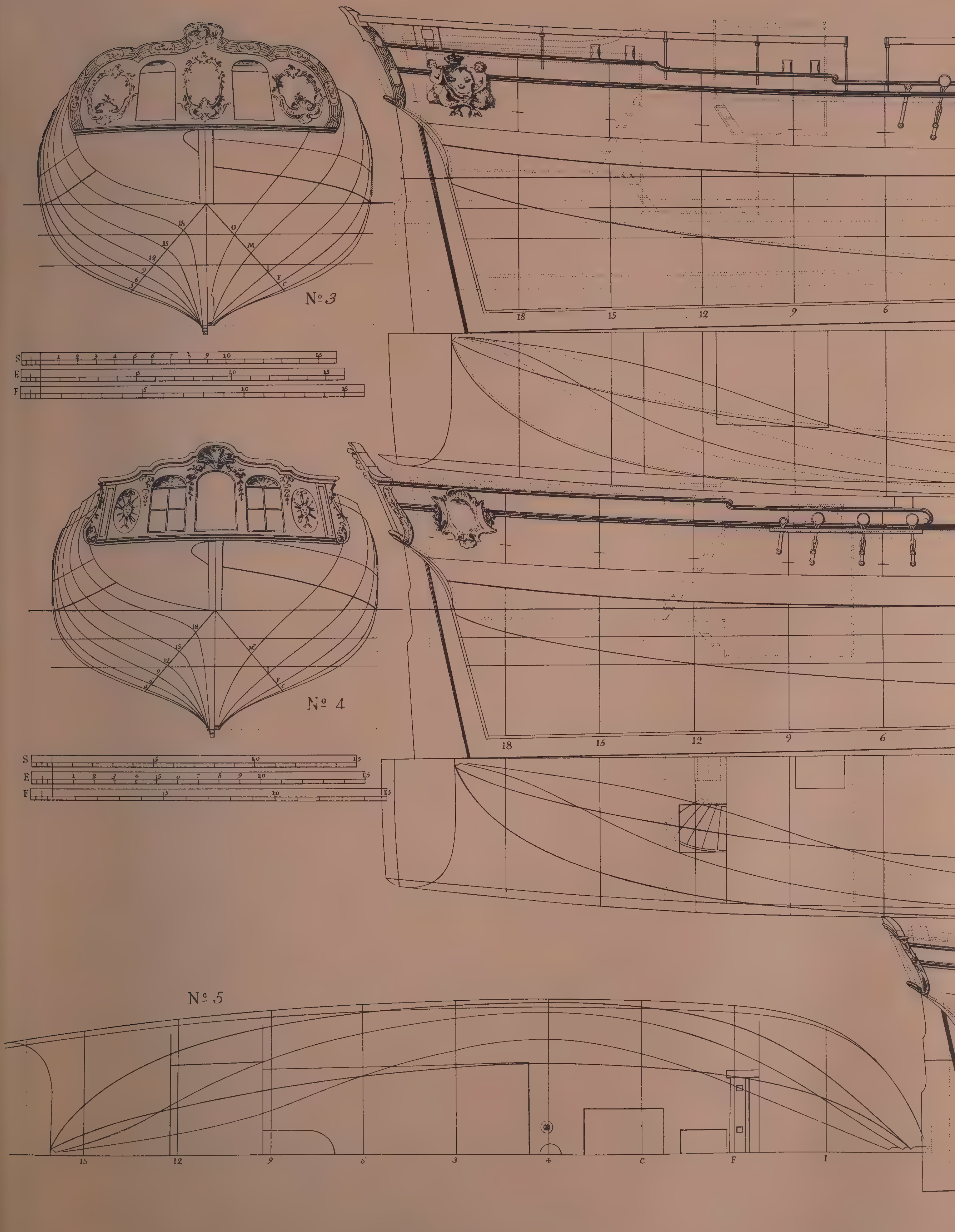
No. 3 is a packet boat with two sorts of frames for either more or less draught of water.

No 4 *Schooner (Packet boats)*

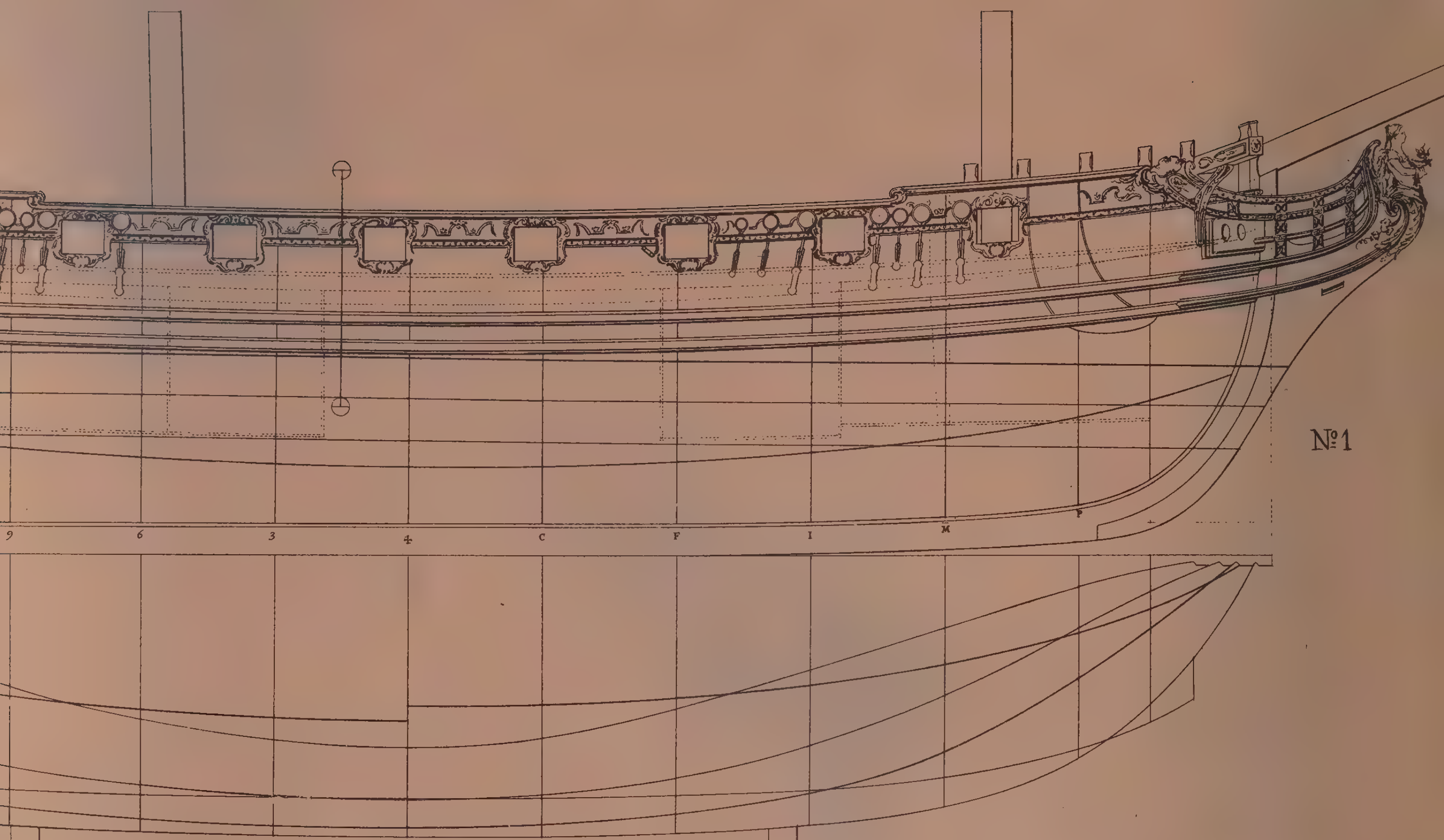
Length between perpendiculars	56ft
Breadth moulded	16ft
Draught as it is in the plan	7ft 3in
Draught laden	7ft 9in
Burthen	16 heavy lasts
Displacement	1909 cu ft

No 5 *Sloop (Packet boats)*

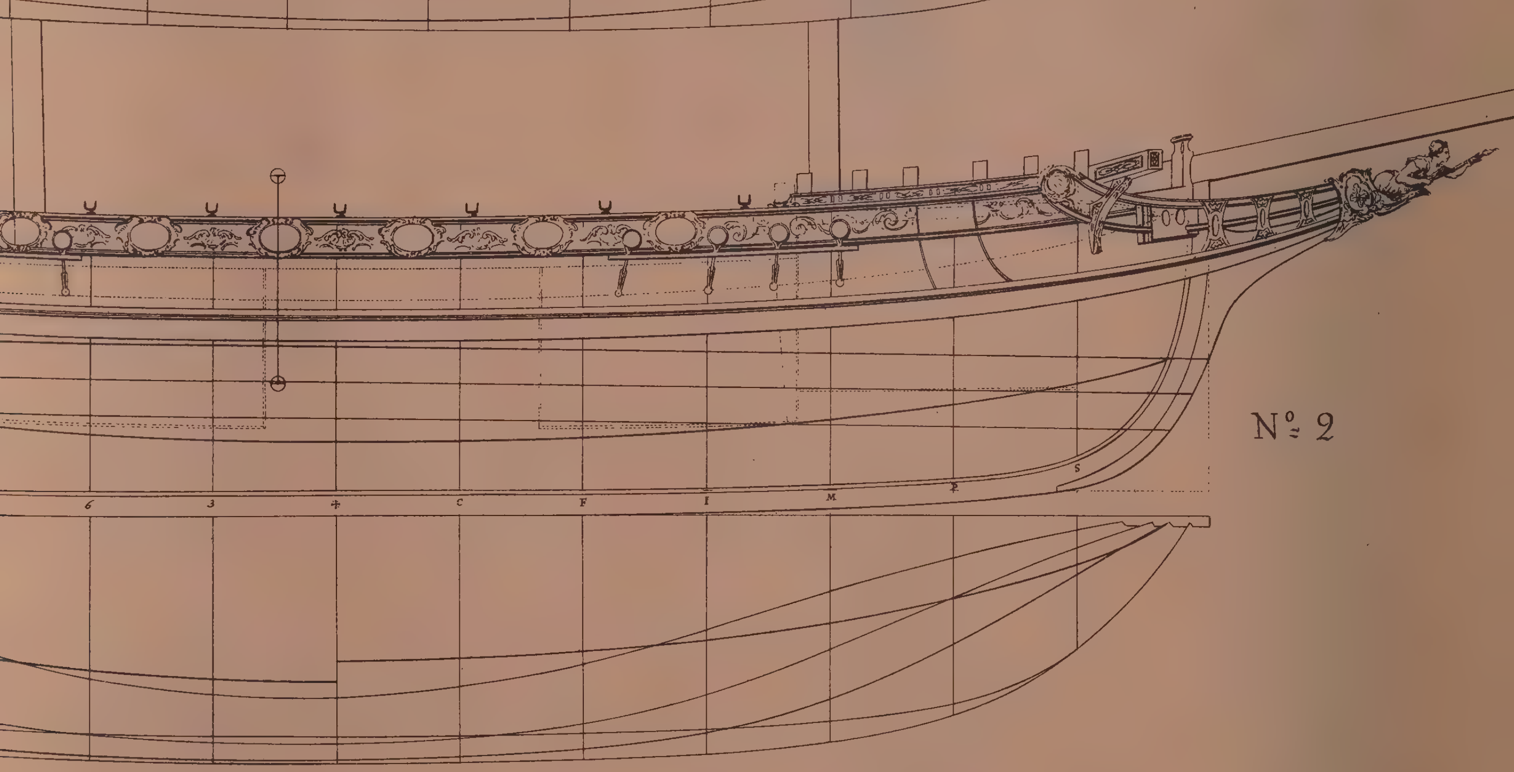
Length between perpendiculars	40ft
Breadth moulded	13 7/12ft
Draught as it is in the plan	5ft 8in
Draught laden	6ft 2in
Burthen	8 heavy lasts
Displacement	819 cu ft


N° 3
N° 4
N° 5

Pl. XLIII



№ 1



N° 2

PLATE XLIII

No 1 *Frigate (Pleasure vessels—for sailing)*

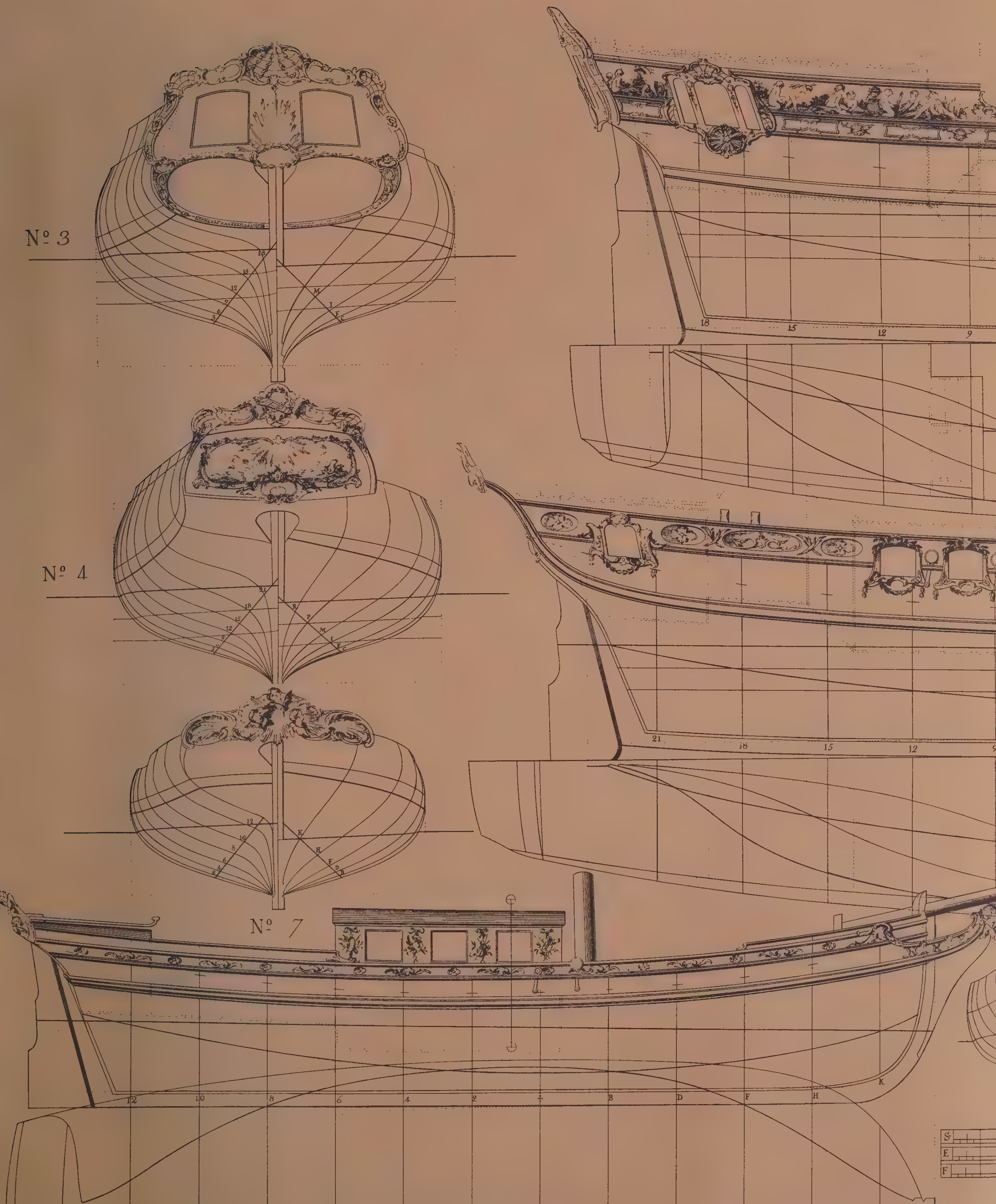
Length between perpendiculars	77 1/2ft
Breadth moulded	23ft
Draught	8 1/2ft
Displacement	4210 cu ft

No 2 *Schooner (Pleasure vessels—for sailing)*

Length between perpendiculars	73 3/4ft
Breadth moulded	19ft
Draught	7ft
Displacement	2830 cu ft
Pairs of oars	6

PLATE XLIV

No 3	*Yacht (Pleasure vessels—for sailing)*	
	Length between perpendiculars	54ft
	Breadth moulded	171/2ft
	Draught	61/2ft
	Displacement	1420 cu ft
No 4	*Schooner (Pleasure vessels—for sailing)*	
	Length between perpendiculars	64ft
	Breadth moulded	17ft
	Draught	6ft
	Displacement	1594 cu ft
	Pairs of oars	6
No 7	*Yacht (Pleasure vessels—for sailing)*	
	Length between perpendiculars	32ft
	Breadth moulded	102/3ft
	Draught	31/12ft
	Displacement	250 cu ft
No 10	*Yacht (Pleasure vessels—for sailing)*	
	Length between perpendiculars	24ft
	Breadt moulded	75/6ft
	Draught	21/2ft
	Displacement	100 cu ft


Nº 3
Nº 4
Nº 7

Pl. XLV.

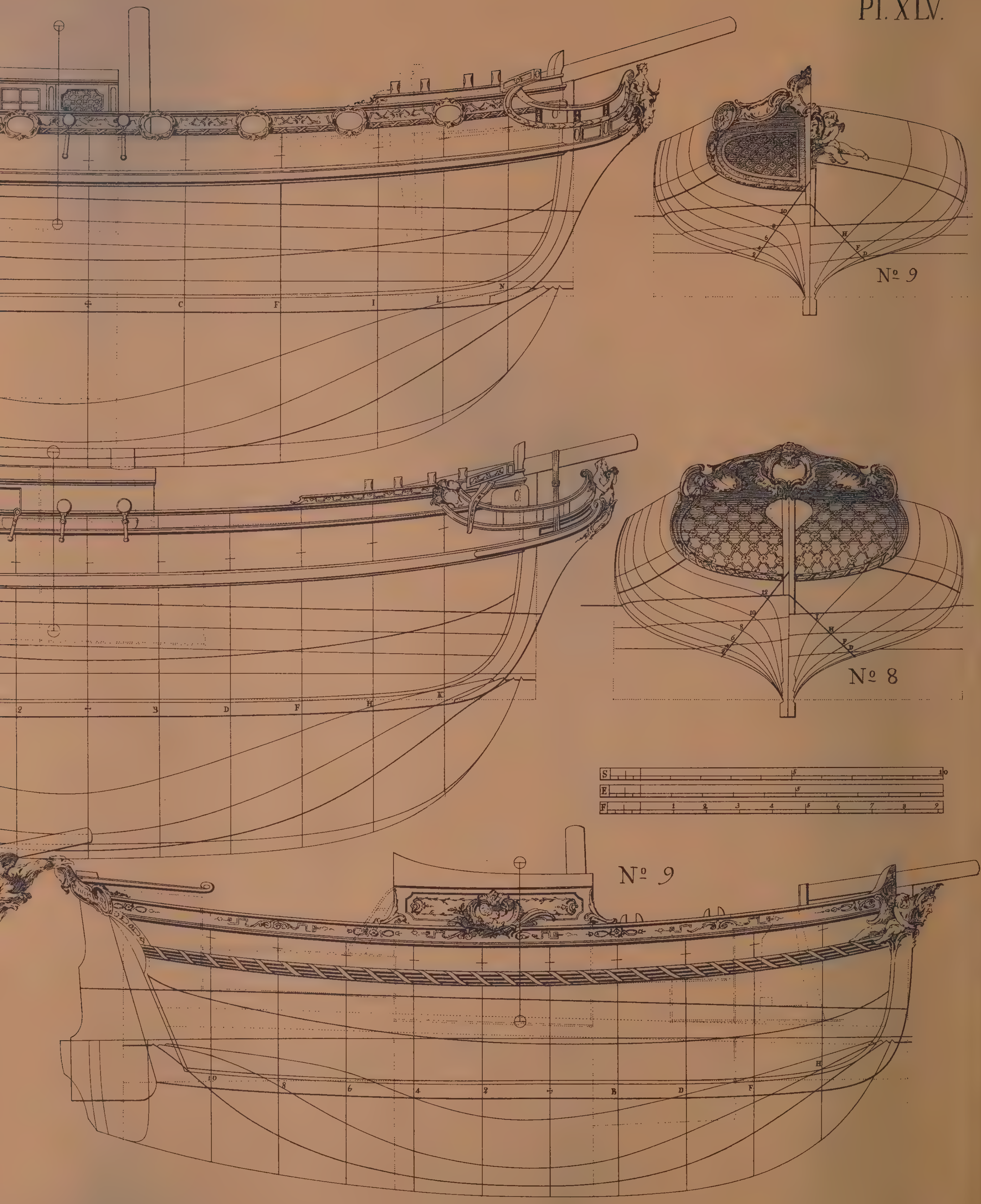


PLATE XLV

No 5	*Yacht (Pleasure vessels—for sailing)*		
	Length between perpendiculars	43 5/6ft	
	Breadth moulded	15 1/4ft	
	Draught	5ft	
	Displacement	742 cu ft	
No 6	*Yacht (Pleasure vessels—for sailing)*		
	Length between perpendiculars	35 3/4ft	
	Breadth moulded	13 1/3ft	
	Draught	4 1/2ft	
	Displacement	474 cu ft	
No 8	*Yacht (Pleasure vessels—for sailing)*		
	length between perpendiculars	30ft	
	Breadth moulded	11 7/12ft	
	Draught	4ft	
	Displacement	280 cu ft	
No 9	*Yacht (Pleasure vessels—for sailing)*		
	Length between perpendiculars	26 1/12ft	
	Breadth moulded	10 5/12ft	
	Draught	3 7/12ft	
	Displacement	175 cu ft	

PLATE XLVI

No 1	*A Rowing Galley*	
	(Pleasure vessels—for rowing and sailing)	
	Length between perpendiculars	124ft
	Breadth moulded	18 7/12ft
	Draught	7ft
	Displacement	4476 cu ft
	Pairs of oars	16

Note:

Plate XLVI No 1 is a pleasure galley with 16 pairs of oars, two men to an oar, with lateen rigging.

Inboard works of the ship:

A) great cabin, B) lobby, C) sleeping cabin, D) dressing room, E) dining cabin, F) sleeping or day cabins, G) galley with two stoves, H) gangway, I) hatchways to the cabins, K) hatch to the cable tier, L) cable tier, M) junior officers' room, N) companion with side windows, O) groove for the anchor cable.

Figure 1 is the stern view of the ship.

Figure 2 ist the view of the bows.

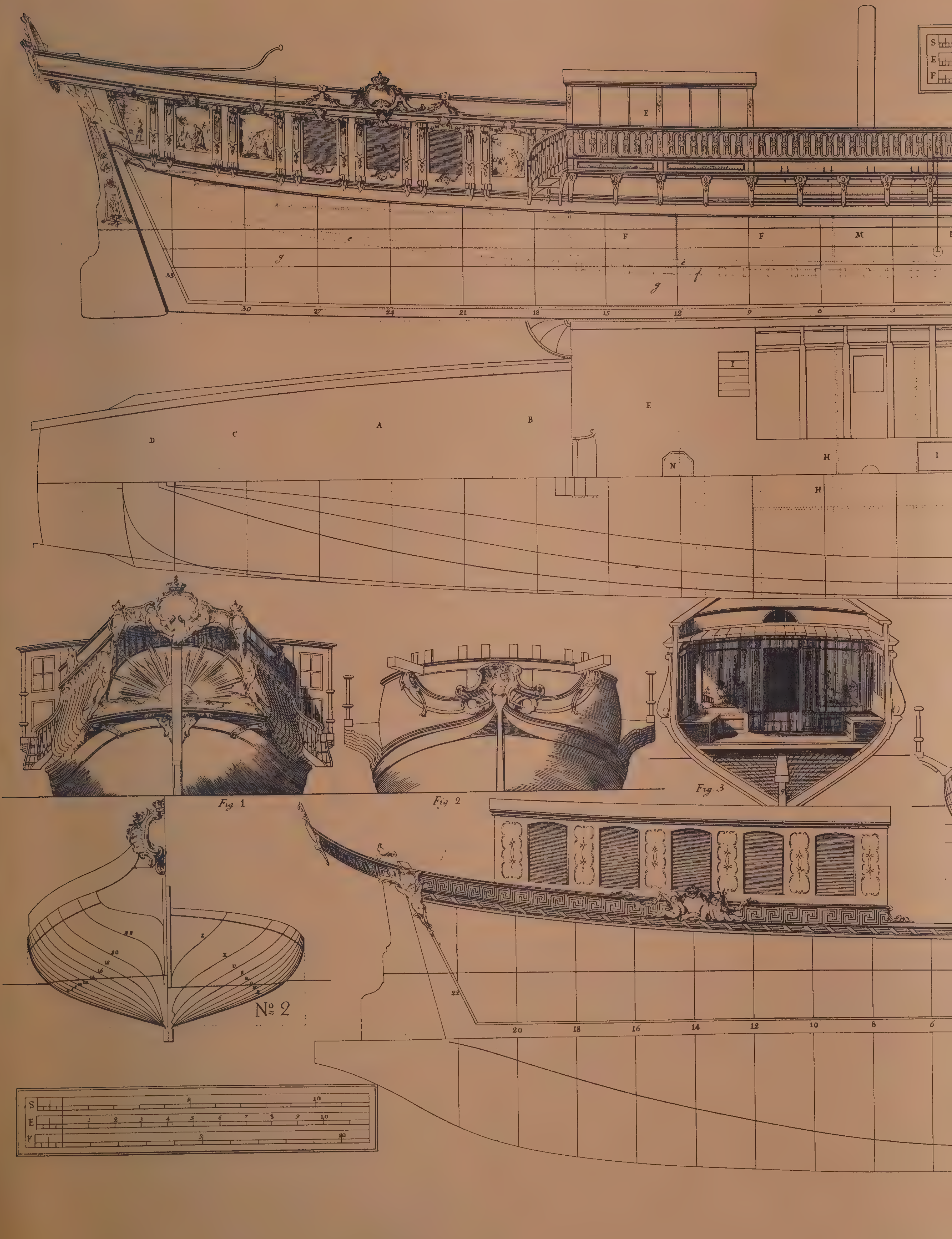
Figure 3 is a profile section at frame 20 looking into the great cabin.

Figure 4 shows the sections.

Figure 5 is a profile section at frame f2. a) steps leading to the poop. b) door to the lobby and down to the great cabin. c) a cabin with two beds.

Figure 6 is a profile section at frame w). d) is the galley entrance. e) the keelson. f) beams joining both sides of the vessel. g) wooden pillars so that the vessel may not sag.

No 2	*A barge (Pleasure vessels—for rowing)*	
	Length between perpendiculars	58 1/4ft
	Breadth moulded	11ft
	Draught	2 2/3ft
	Pairs of oars	10



S
E
F
E
F
F
M
30
27
24
21
18
15
12
9
6
3
I
E
A
B
D
C
N
H
I
H
Fig 1
Fig 2
Fig.3
№ 2
20
18
16
14
12
10
8
6
S
E
F
1
2
3
4
5
6
7
8
9
10

Pl. XLVII.

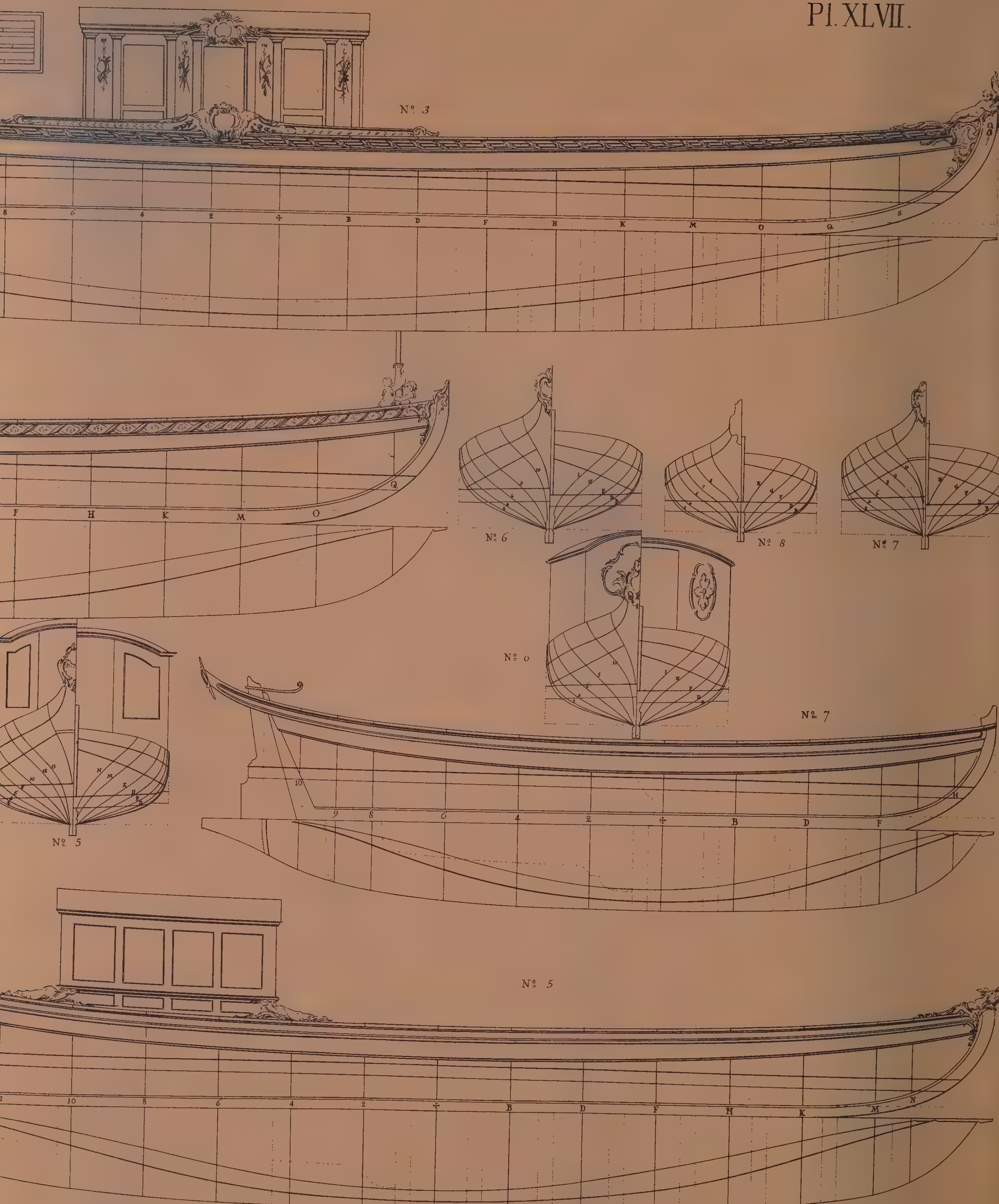


PLATE XLVII

No 3 *A barge (Pleasure vessels—for rowing)*

Length between perpendiculars	52ft
Breadth moulded	71/3ft
Draught	21/12ft
Pairs of oars	12

No 4 *A barge (Pleasure vessels—for rowing)*

Length between perpendiculars	432/3ft
Breadth moulded	67/12ft
Draught	21/12ft
Pairs of oars	10

No 5 *Shallow draught barge (Pleasure vessels—for rowing)*

Length between perpendiculars	365/6ft
Breadth moulded	61/3ft
Draught	12/3ft
Pairs of oars	8

No 6 *A barge with two sorts of frames (Pleasure vessels—for rowing)*

Length between perpendiculars	281/6ft
Breadth moulded	6ft
Draught	12/3ft
Pairs of oars	7 or 8

Note:

with the fuller frames there is a cabin aft and the vessel is propelled by 7 pairs of oars; with the sharper frames there is no cabin and 8 pairs of oars can be used.

No 7 *Barge or pinnace (Pleasure vessels—for rowing)*

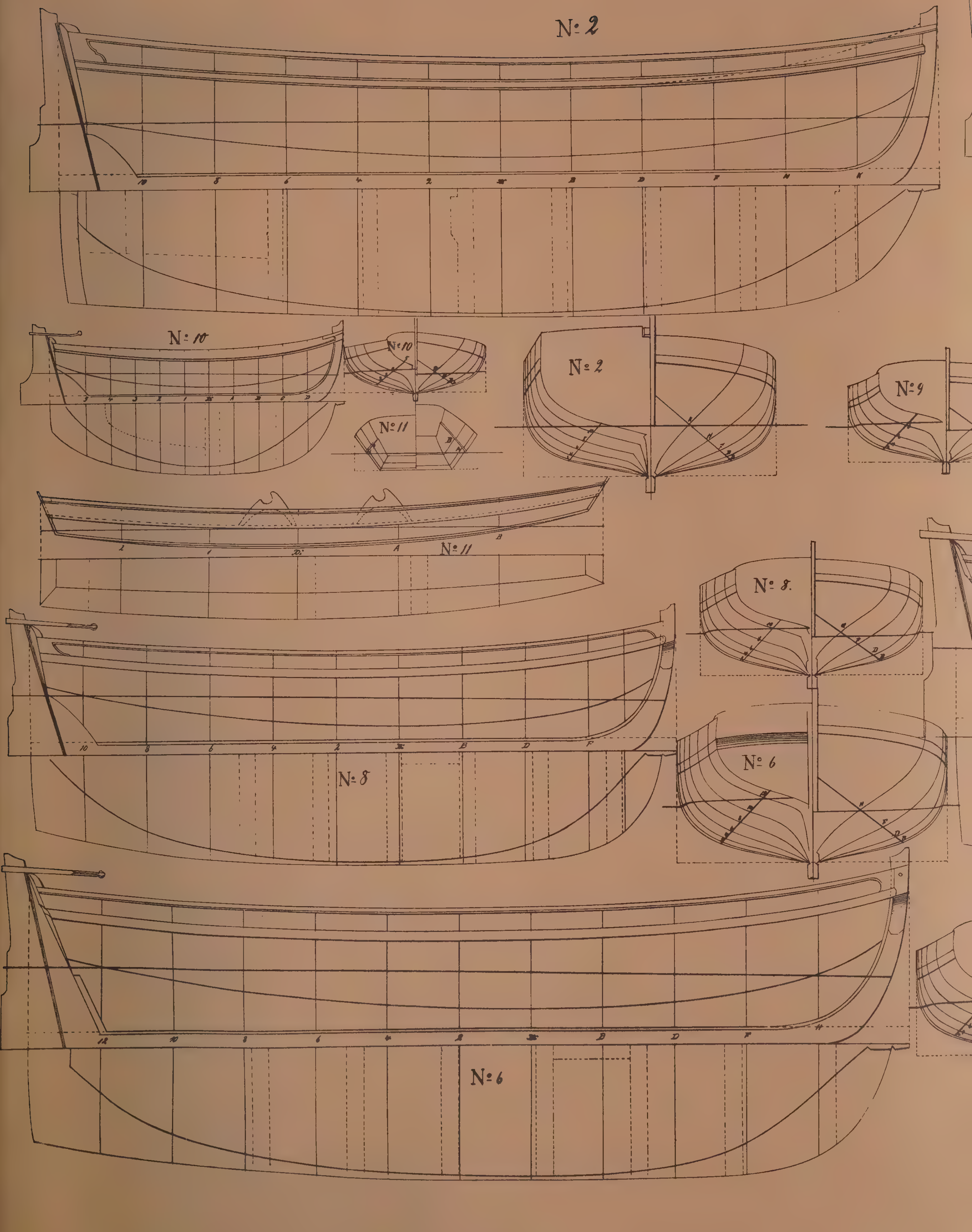
Length between perpendiculars	241/12ft
Breadth moulded	57/12ft
Draught	12/3ft
Pairs of oars	5

No 8 *Yawl (Pleasure vessels—for rowing)*

Length between perpendiculars	201/3ft
Breadth moulded	5ft
Draught	12/3ft
Pairs of oars	4

PLATE XLVIII

No 2	*Launch (Boats for the use of ships)*		
	Length between perpendiculars	30ft	
	Breadth moulded	8 2/3ft	
	Pairs of oars	7	
No 3	*Launch (Boats for the use of ships)*		
	Length between perpendiculars	25ft	
	Breadth moulded	7 1/3ft	
	Pairs of oars	6	
No 5	*Longboat (Boats for the use of ships)*		
	Length between perpendiculars	34ft	
	Breadth moulded	10ft	
	Pairs of oars	8	
No 6	*Longboat (Boats for the use of ships)*		
	Length between perpendiculars	29 1/6ft	
	Breadth moulded	9 1/4ft	
	Pairs of oars	7	
No 7	*Longboat (Boats for the use of ships)*		
	Length between perpendiculars	25 1/4ft	
	Breadth moulded	8 2/3ft	
	Pairs of oars	7	
No 8	*Longboat (Boats for the use of ships)*		
	Length between perpendiculars	22ft	
	Breadth moulded	7 7/12ft	
	Pairs of oars	6	
No 9	*Longboat (Boats for the use of ships)*		
	Length between perpendiculars	18 1/12ft	
	Breadth moulded	6 2/3ft	
	Pairs of oars	5	
No 10	*Yawl (Boats for the use of ships)*		
	Length between perpendiculars	10ft	
	Breadth moulded	4 5/6ft	
	Pairs of oars	2	
No 11	*Yawl or Pram (Boats for the use of ships)*		
	Length between perpendiculars	19 1/4ft	
	Breadth moulded	4 1/4ft	
	Pairs of oars	2	



N° 2
N° 10
N° 10
N° 2
N° 9
N° 11
N° 11
N° 8.
N° 8
N° 6
N° 6

Pl. XLIX

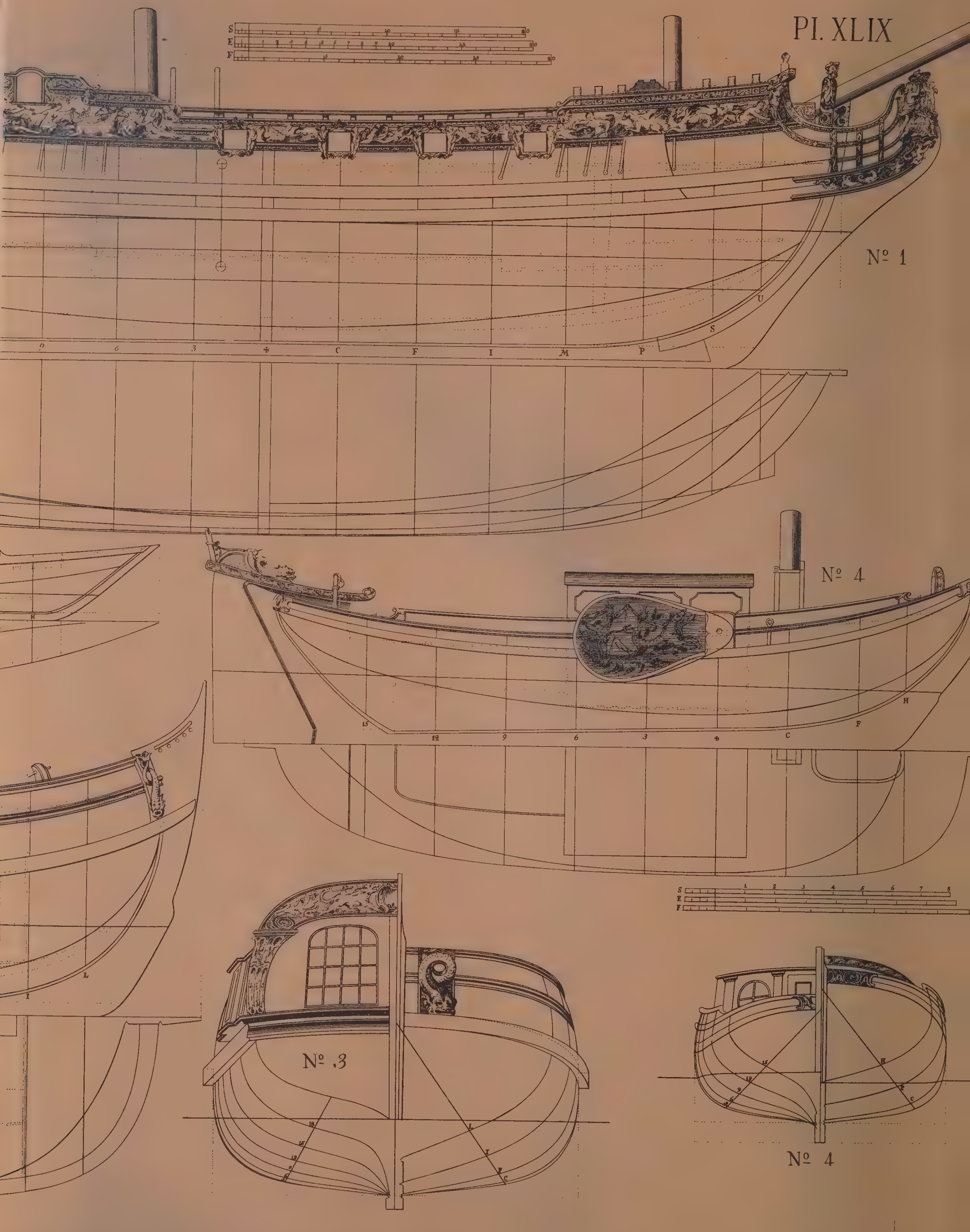


PLATE XLIX

No 1	*The Yacht* Caroline *(Vessels of war)* belonging to His Brittanick Majesty		
	Length between perpendiculars		93 1/2ft
	Breadth moulded		24 2/3ft
	Draught		11ft
	Guns	12	3-pounders on the deck
	Swivel guns	14	
	Pairs of oars	5	
No 2	*English eight-oared barge (Different sorts of smaller vessels)*		
	Length between perpendiculars		45 1/4ft
	Breadth moulded		6 5/12ft
No 3	*A Dutch Heerenyacht (Different sorts of smaller vessels)*		
	Length between perpendiculars		47 2/3ft
	Breadth moulded		16 1/6ft
	Draught		4ft
No 4	*A Dutch schuit (Different sorts of smaller vessels)*		
	Length between perpendiculars		26ft
	Breadth moulded		8 7/12ft

PLATE L

No 5 *A Swedish boyer (Different sorts of smaller vessels)*
Length between perpendiculars 345/6ft
Breadth moulded 12ft

No 6 *A Norway yawl (Different sorts of smaller vessels)*
Length between perpendiculars 225/12ft
Breadth moulded 8ft

No 7 *A Spanish bark used in Cadiz*
(Different sorts of smaller vessels)
Length between perpendiculars 462/3ft
Breadth moulded 125/6ft

No 8 *A Venetian gondola (Different sorts of smaller vessels)*
Length between perpendiculars 43ft
Breadth moulded 47/12ft

No 9 *An English ferry with four oars*
(Different sorts of smaller vessels)
Length between perpendiculars 267/12ft
Breadth moulded 5ft

No 10 *A Greenland pinnace for whale-fishing*
(Different sorts of smaller vessels)
Length between perpendiculars 251/4ft
Breadth moulded 511/12ft

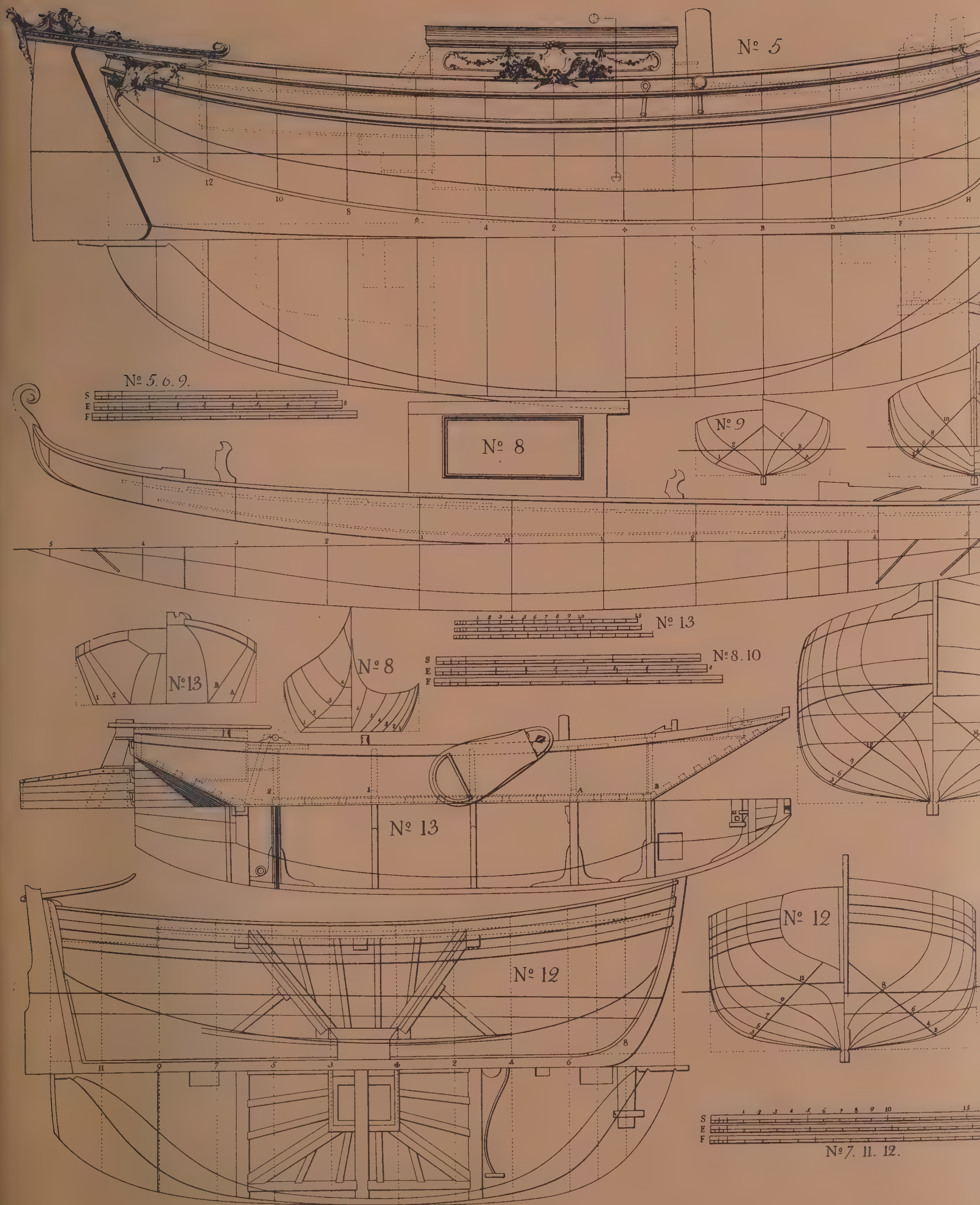
No 11 *An English hoy or lighter*
(Different sorts of smaller vessels)
(Rigging see plate LXII, No 14)
Length between perpendiculars 542/3ft
Breadth moulded 17ft
Draught 81/6ft

No 12 *A hopper from Newcastle for carrying ballast*
(Different sorts of smaller vessels)
Length between perpendiculars 391/4ft
Breadth moulded 163/4ft

Note: this vessel is used in Newcastle, England to carry ballast from ships to sea. In the bottom there are two openings with traps through which the ballast is dropped.

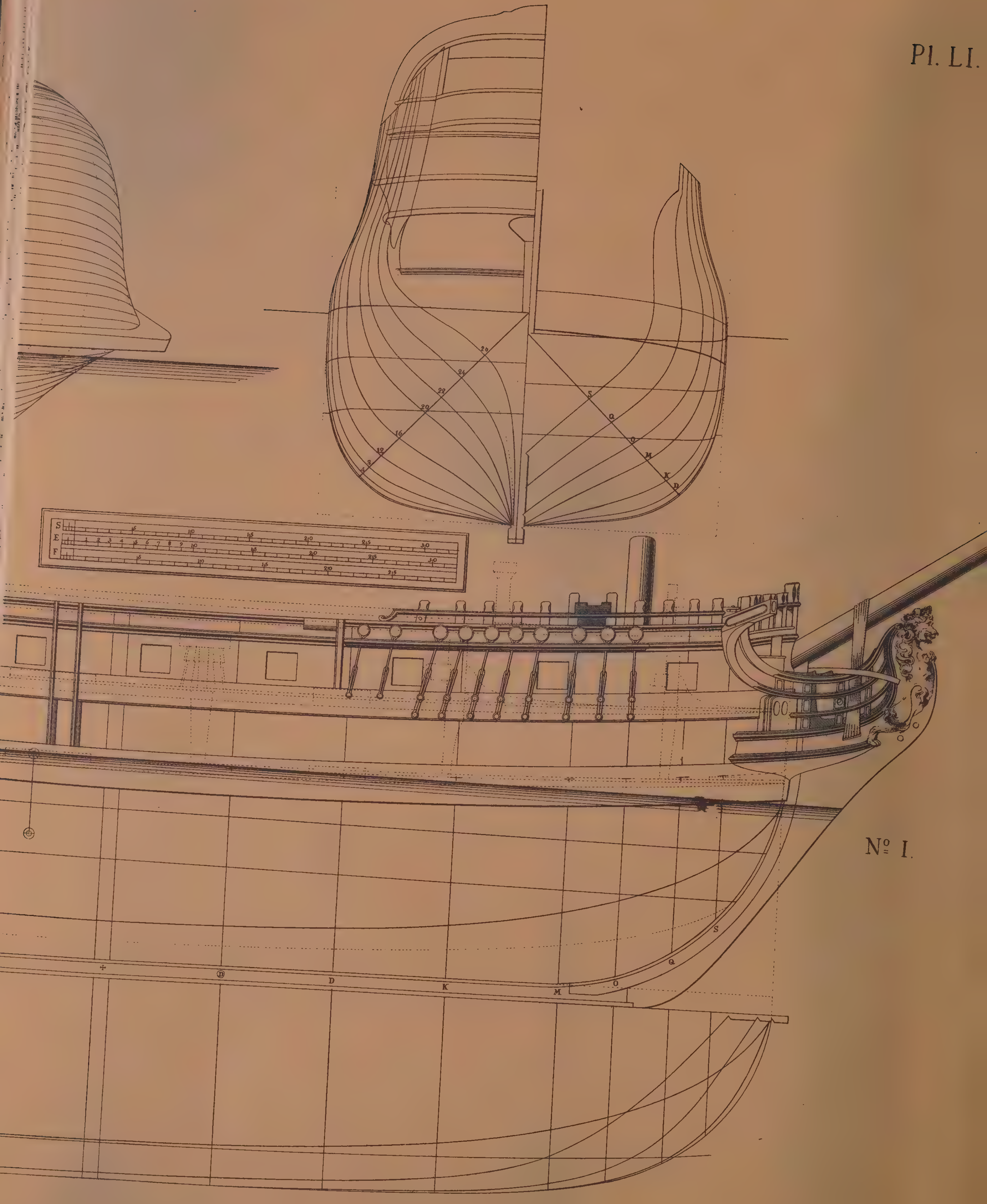
No 13 *An English chalk barge*
(Different sorts of smaller vessels)
Length between perpendiculars 571/2ft
Breadth moulded 152/3ft

Note: This flat-bottomed vessel carries chalk in London waters: she is rigged with a four-cornered spritsail and a forestaysail, and sails very well.



Nº 5
Nº 5. 6. 9.
S
E
F
Nº 8
Nº 9
Nº 13
Nº 8
Nº 8. 10
Nº 13
Nº 13
Nº 12
Nº 12
Nº 7. 11. 12.

Pl. LI.



Nº I.

PLATE LI

No 1 *English East Indiaman (Merchant ships or vessels)*

Length between perpendiculars	135 1/2ft
Breadth moulded	34 2/3ft
Draught	19 3/4ft
Burthen	314 heavy lasts
Displacement	52333 cuft

above left:

ship careened

PLATE LII

No 2 *English West India trader (Merchant ships or vessels)*

Length between perpendiculars	102ft
Breadth moulded	27 1/2ft
Draught	16 1/4ft
Burthen	140 heavy lasts
Displacement	22896 cu ft

No 3 *English sloop (Merchant ships or vessels)*

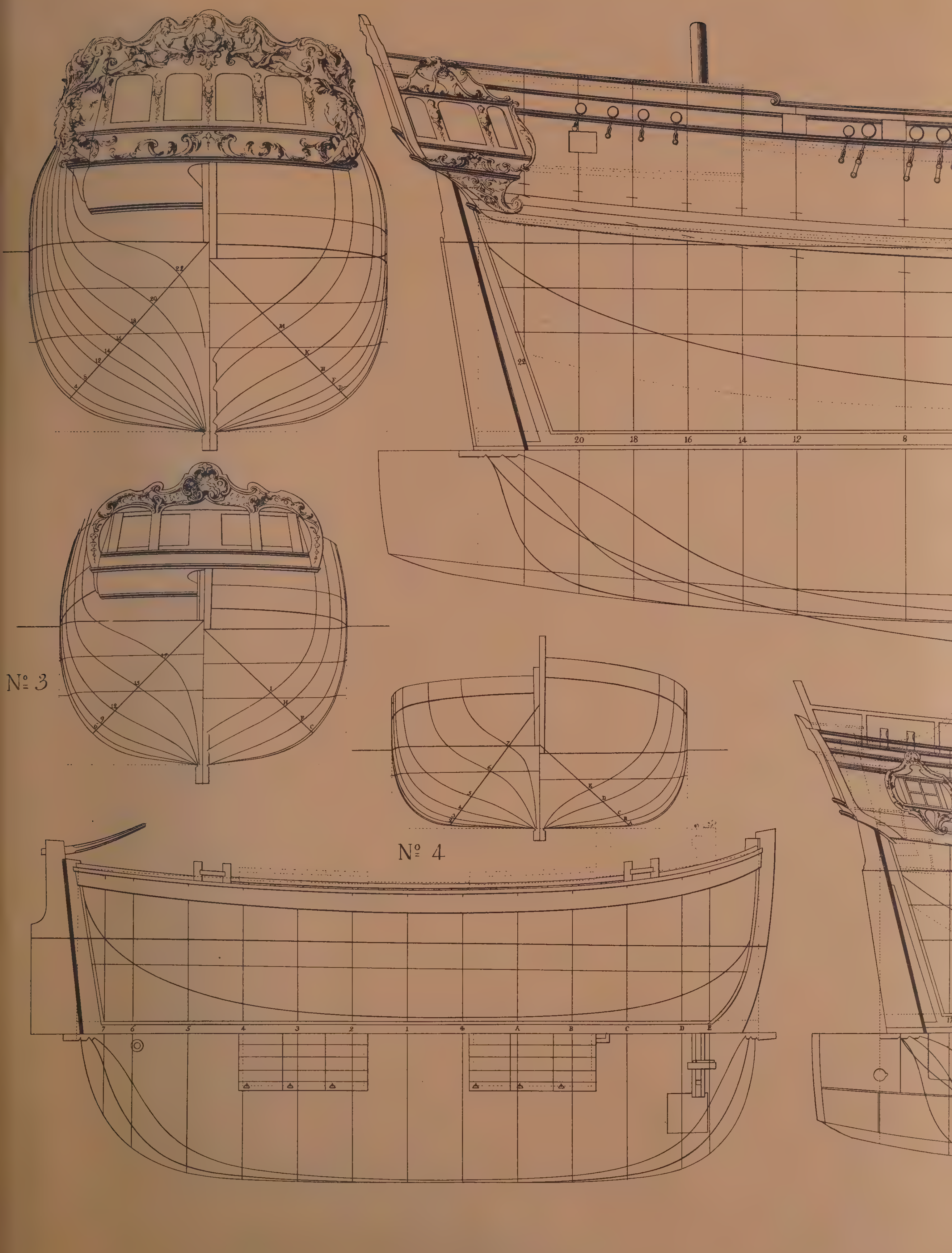
Length between perpendiculars	58 2/3ft
Breadth moulded	18 1/4ft
Draught	10 1/2ft
Burthen	39 heavy lasts
Displacement	5708 cu ft

Note:

An English sloop built to carry passengers as well as to transport wine from France to London

No 4 *English close lighter for carrying grain (Different sorts of smaller vessels)*

Length between perpendiculars	45ft
Breadth moulded	18 1/2ft
Draught	6ft



Nº 3
Nº 4
20 18 16 14 12 8
7 6 5 4 3 2 1 A B C D E

Pl. LIII.

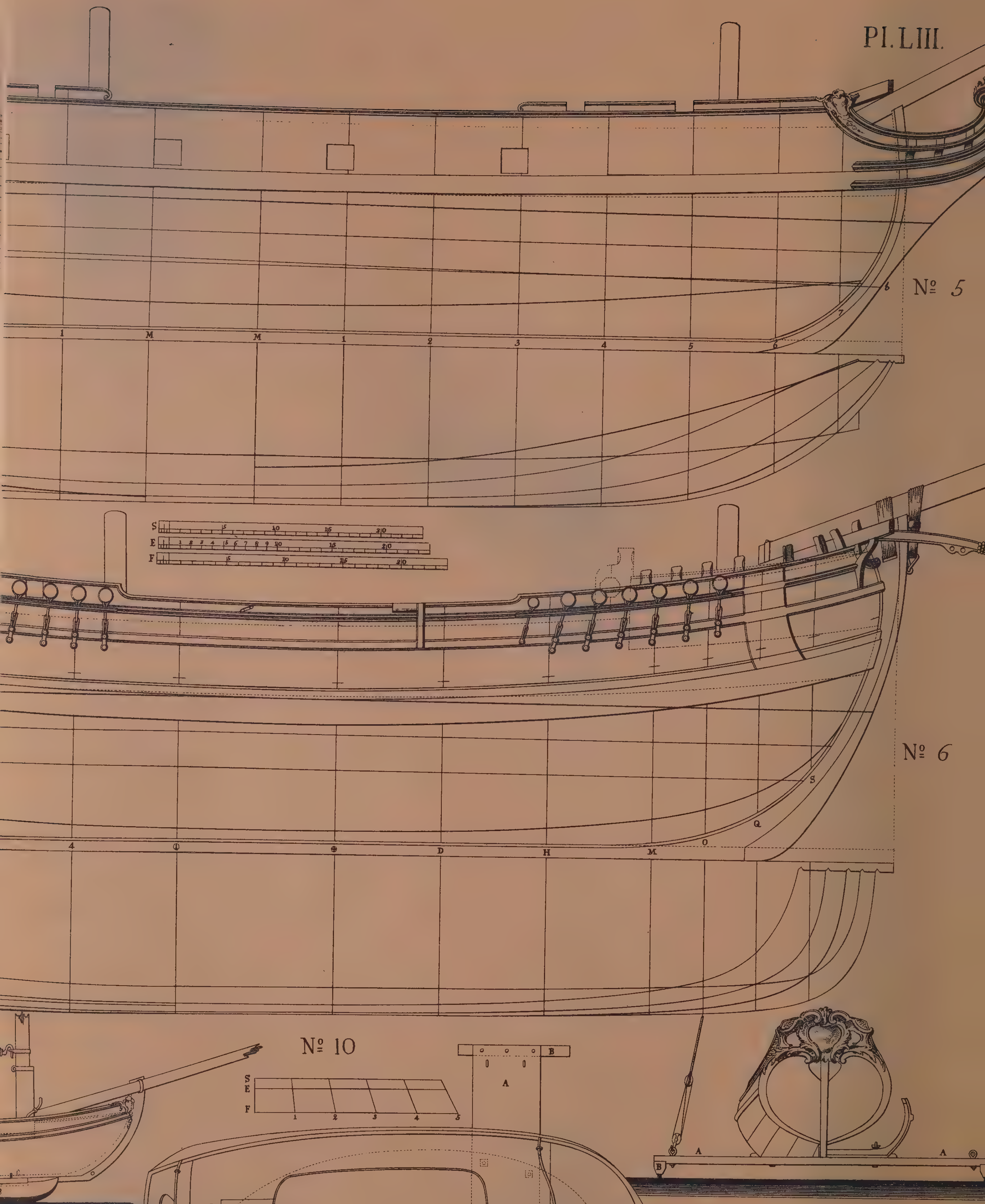


PLATE LIII

No 5 *The fly-boat or flight* Le Chameau
(Merchant ships or vessels)

Length between perpendiculars	152 1/2ft
Breadth moulded	34 1/4ft
Draught	15 1/4ft

Note:

The fly-boat *Le Chameau* is a store-ship belonging to the French crown and sails particularly well.

No 6 *A Dutch fly-boat or flight (Merchant ships or vessels)*

Length between perpendiculars	136ft
Breadth moulded	30ft
Draught	15ft

No 10 *Boat for sailing on the ice*

Note:

No. 10 is an ice boat. A is a broad plank which is fastened to the keel by four iron bolts; beneath this are two runners BB shod with iron. D is a lever and attached to it is a pointed iron bolt for stopping the boat. When lever D is pressed down by the foot the bolt is pushed in to the ice. As soon as the foot is lifted the arm is raised by spring C

No 11 *Rigging of the ice boat*

Note:

No. 11 shows the very large sails of these boats.

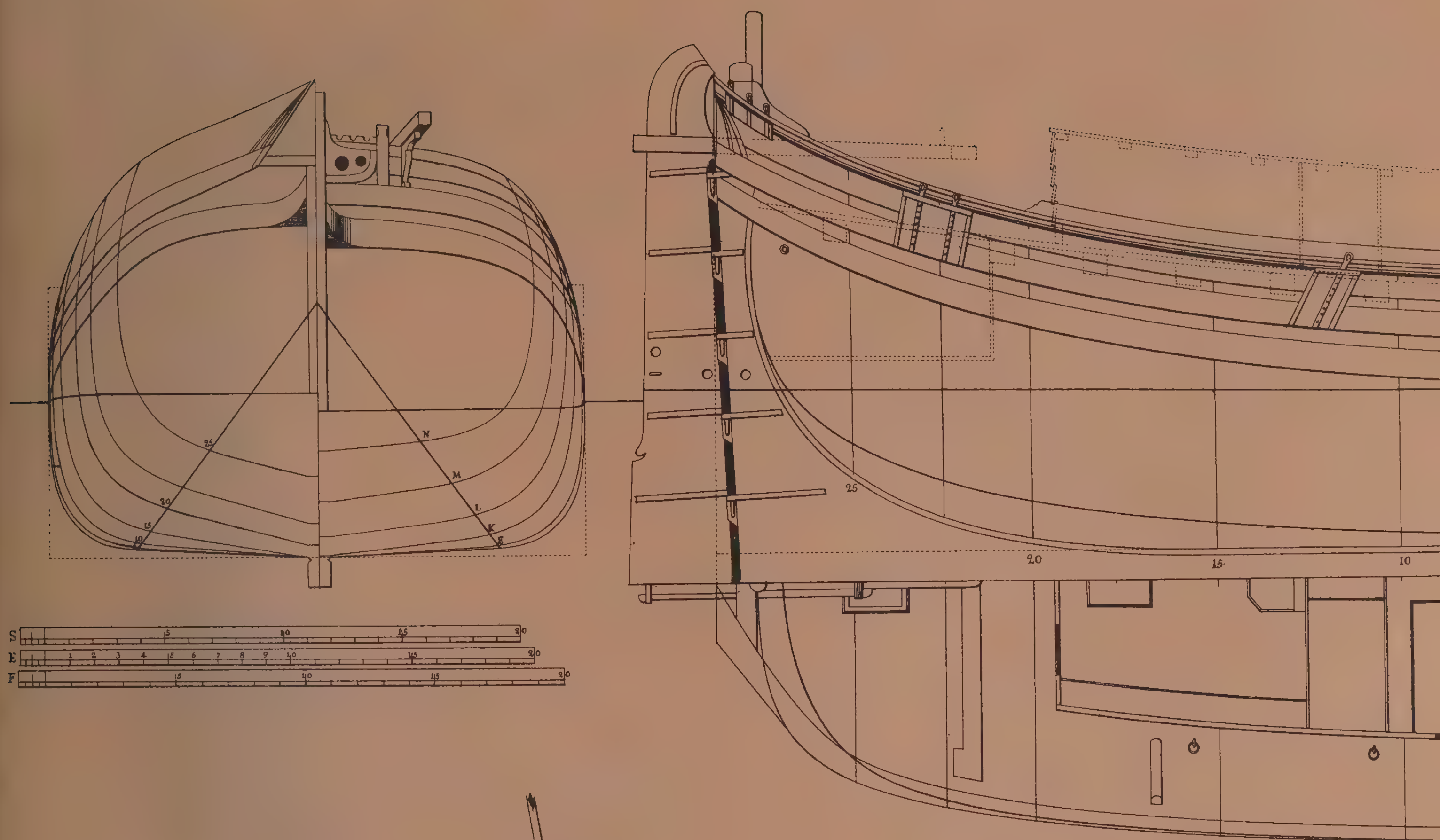
PLATE LIV

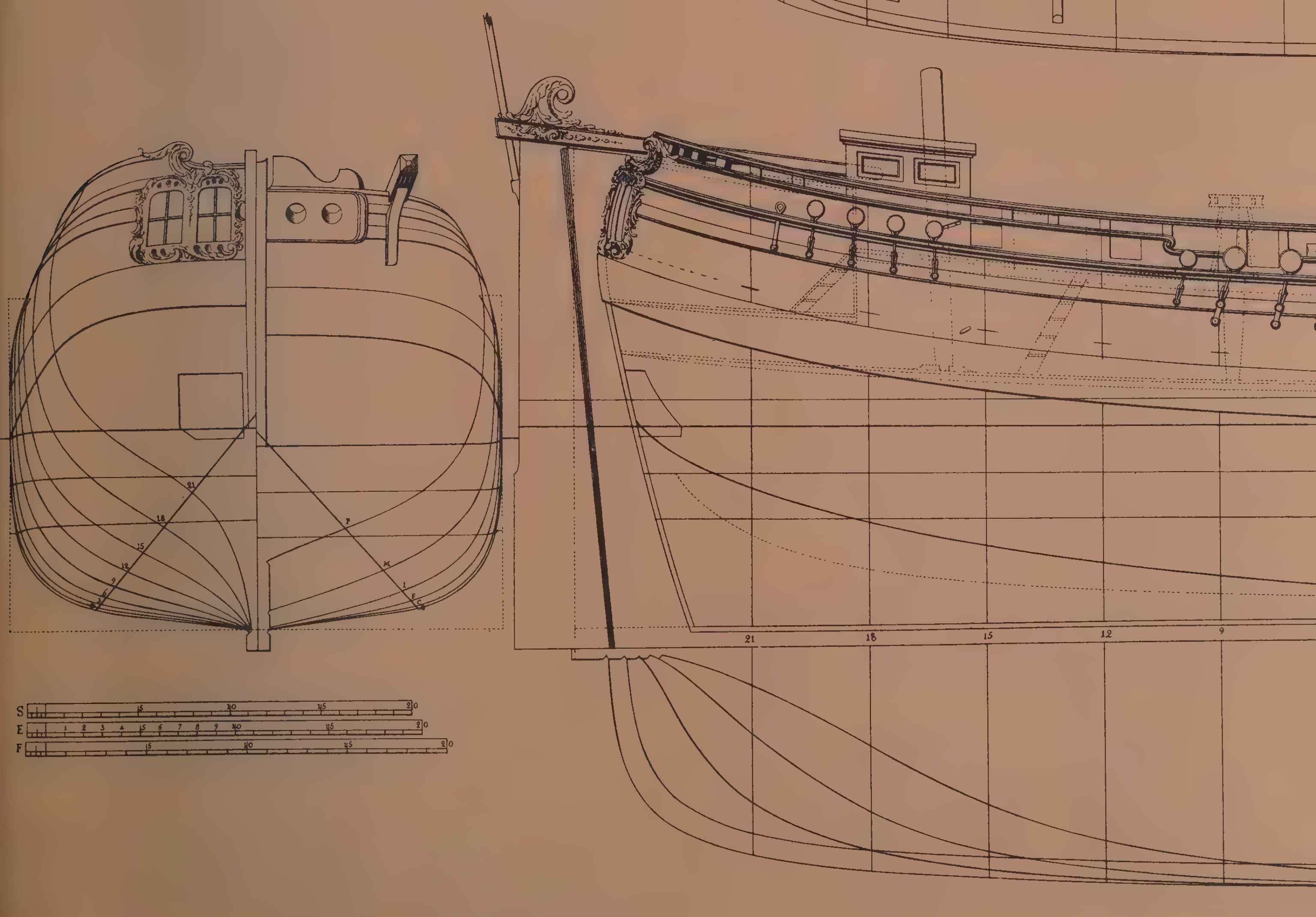
No 7 *A Dutch smack (Merchant ships or vessels)*

Length between perpendiculars	90 1/4ft
Breadth moulded	22 1/2ft
Draught	8 3/4ft

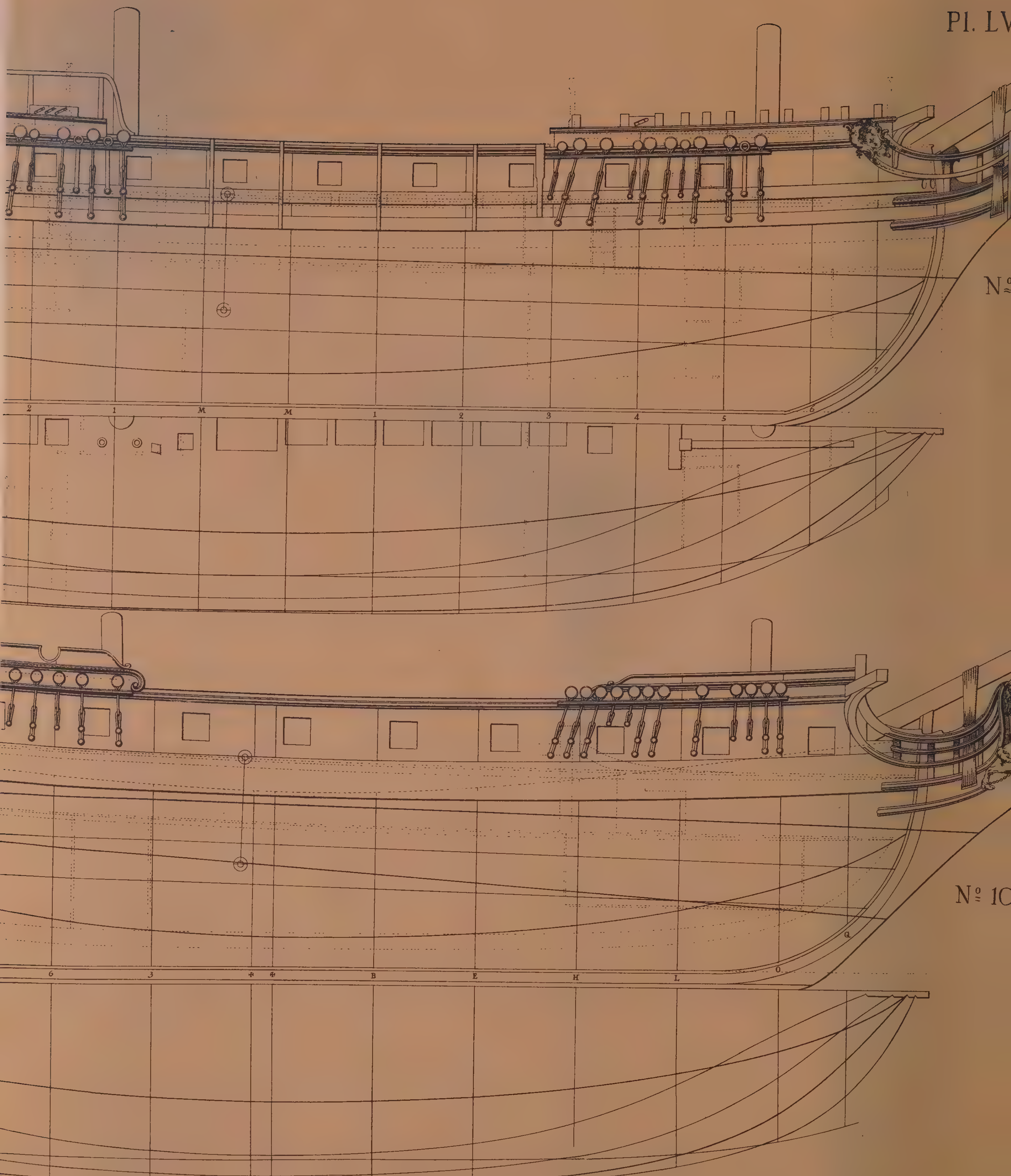
No 8 *A Dutch galiot or hoy with three masts (Merchant ships or vessels)*

Length between perpendiculars	110 1/4ft
Breadth moulded	27ft
Draught	13 7/12ft





Pl. LV



N°

N° 10

PLATE LV

No 9 *Frigate* La Sirenne *(Vessels of war)*

Length between perpendiculars	131 1/4ft
Breadth moulded	34 1/3ft
Draught	15 1/2ft
Displacement	27222 cu ft
Guns	34
of which	26 8-pounders on the deck
	8 4-pounders on the quarter-deck and forecastle

Note:

No. 9 is the French naval frigate *La Sirenne*, an excellent sailer able to carry a press of sail without too great an inclination.

No 10 *Frigate* The Unicorn *(Vessels of war)*

Length between perpendiculars	125 1/4ft
Breadth moulded	34 1/6ft
Draught	17 1/4ft
Displacement	27742 cu ft
Guns	34
of which	24 8-pounders on the deck
	10 4-pounders on the fore-castle and quarterdeck

Note:

No. 10 is an English naval frigate, *The Unicorn*, a fast vessel. The line running at an angle up towards the stern is the launching draught of water line.

PLATE LVI

No 11 *Frigate* Jaramas *(Vessels of war)*

Length between perpendiculars		126 3/4ft
Breadth moulded		33ft
Draught		17 1/6ft
Displacement		27648 cuft
Guns		32
of which	22	8-pounders on the deck
	10	4-pounders on the forecastle and quarterdeck

Note:

No. 11 is the Swedish naval frigate *Jaramas*, an excellent sailer.

No 12 *Frigate* Blaa Hejren *(Vessels of war)*

Length between perpendiculars		89 1/3ft
Breadth moulded		23 1/2ft
Draught		12 1/6ft
Displacement		9785 cuft
Guns:	18	4-pounders on the deck

Note:

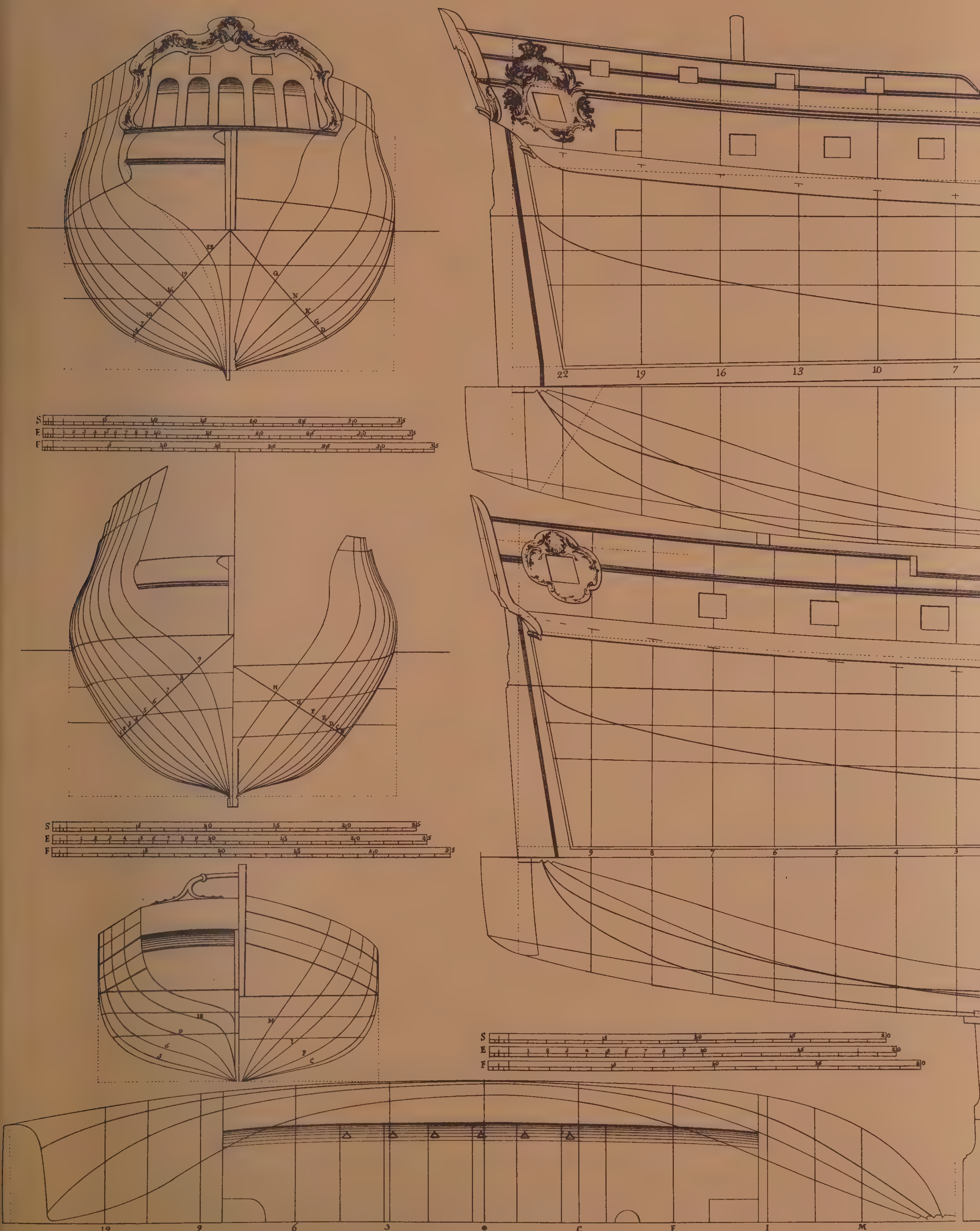
No. 12 is the Danish naval frigate *Blaa Hejren*, an excellent sailer but very crank.

No 19 *Galeass, a Baltick vessel (Different sorts of smaller vessels)*

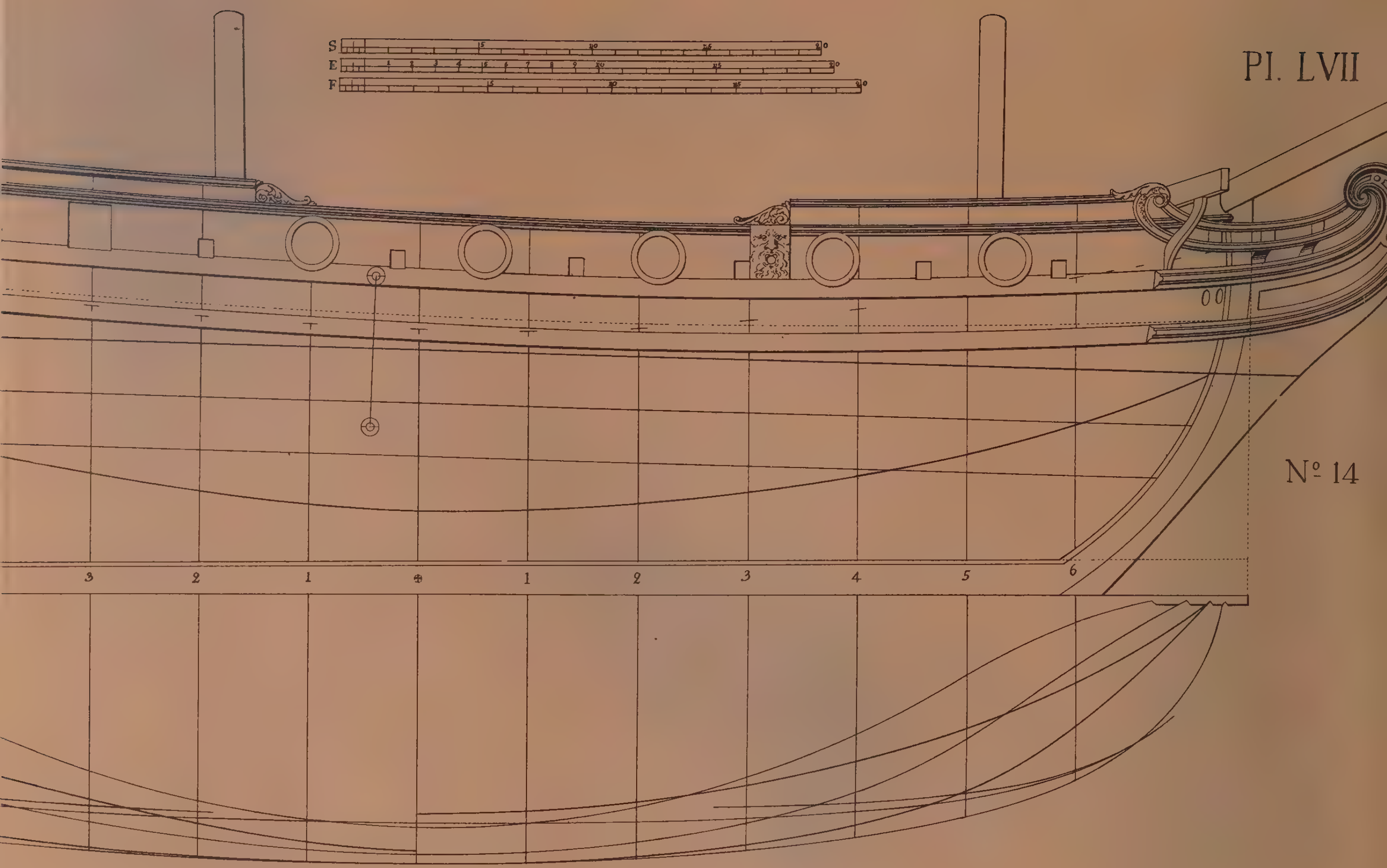
Length between perpendiculars	50ft
Breadth moulded	14 5/6ft
Draught	5 1/2ft

Note:

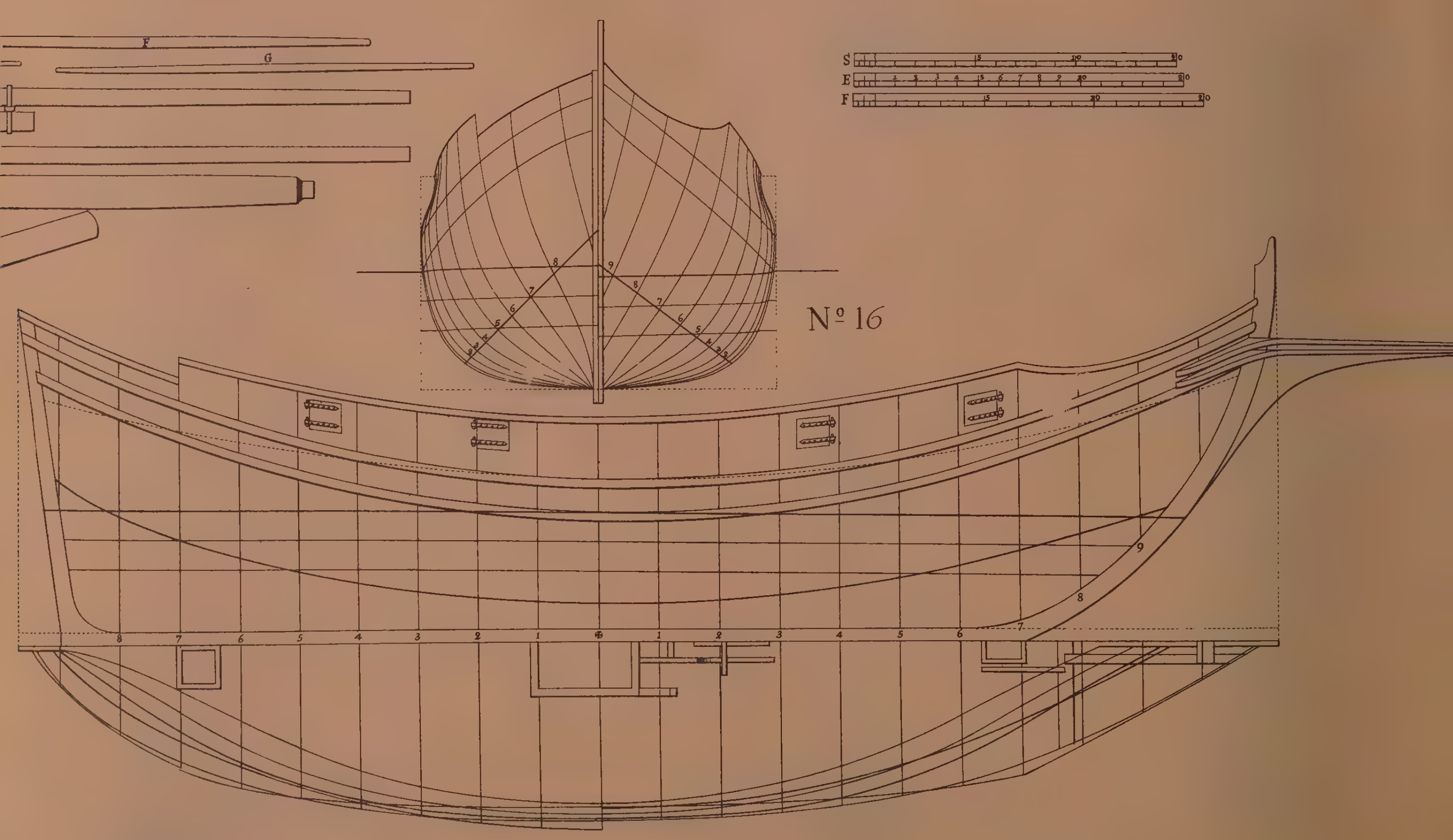
No. 19 is a vessel used on lakes and rivers to carry merchandise and passengers.


22 19 16 13 10 7
9 8 7 6 5 4 3
12 9 6 3 C F I M

Pl. LVII



N° 14



N° 16

PLATE LVII

No 14 *Frigate* Neptunus *(Vessels of war)*

Length between perpendiculars	82ft
Breadth moulded	231/4ft
Draught	113/4ft
Displacement	7477 cu ft
Guns	16 6-pounders on deck
Swivel guns	8
Pairs of oars	4

Note:

No. 14 is a Flemish fighting vessel built in Ostend at the end of the last century: an especially good sailer.

No 15 *Bermuda sloop (Vessels of war)*

Length between perpendiculars	651/2ft
Breadth moulded	213/4ft
Draught	122/3ft
Displacement	4751 cu ft
Guns	10 4-pounders on deck
Swivel guns	12

Note:

No. 15 is a Bermuda sloop, a vessel often used in West indian waters

A) mast, B) bowsprit and jib-boom, C) boom, D) gaff, E) cross-jack, F) topsail yard, G) topgallant yard

No 16 *A French tartane (Vessels of war)*

Length between perpendiculars	621/4ft
Breadth moulded	177/12ft
Draught	62/3ft
Guns	8 4-pounders on deck
Swivel guns	4

Note:

No. 16 is a tartane used in the Mediterranean both to carry merchandise and as a fighting ship

PLATE LVIII

No 17 *An Algerian xebec (Vessels of war)*

Length between perpendiculars		130 1/3ft
Breadth moulded		25 1/4ft
Draught		9 2/3ft
Guns		28
of which	16	6-pounders on the deck
	4	12-pounders on the forecastle
	8	3-pounders on the quarterdeck
Musquetoons		30
Pairs of oars		9

Note:

No. 17 is an Algerian xebec.

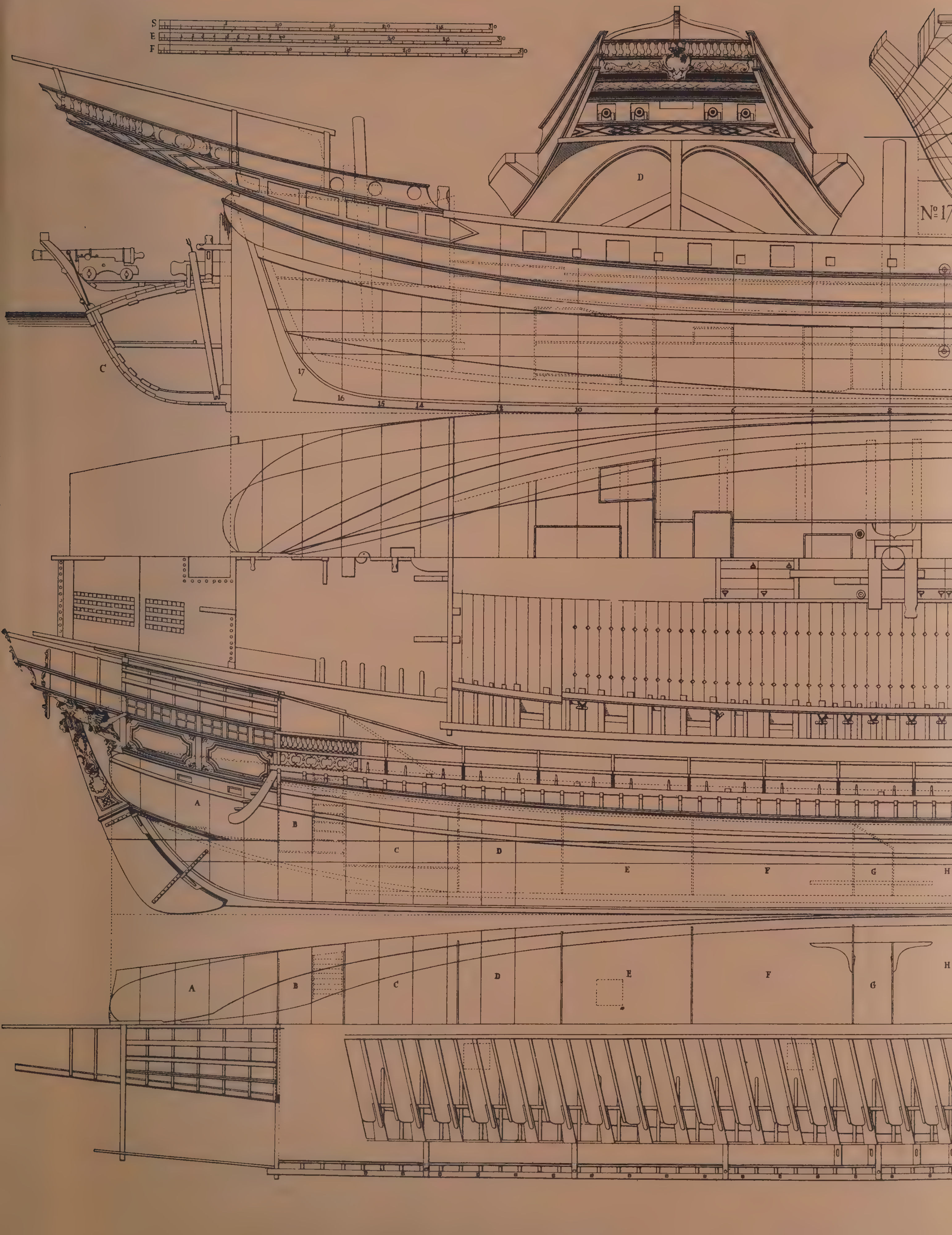
A) profile section in the cabin, B) profile section aft of the fore-mast, C) profile section at the midship frame, D) view of the stern.

No 18 *Maltese galley* La Capitana *(Vessels of war)*

Length between perpendiculars		184ft
Breadth moulded		24 5/6ft
Draught		8 1/2ft
Guns		5
of which	2	8-pounders on the deck
	2	6-pounders on the deck
	1	36-pounders on the forecastle
Swivel guns		18
Musquetoons		18
Pairs of oars		30

Note:

No. 18 is a rowing galley from Malta with 30 banks of oars, 5 men to each oar. A) cabin, B) cuddy, C) officers' ward-room, D) room for officers' stores, E) bread-room, F) store-room, G) magazine, H) gun-room, I) large hold, K) cockpit, LL) room for the boatswain and his stores, M) profile section at the midship frame or broadest part of the galley.



S
E
F
D
C
17
16
15
14
12
10
8
6
4
2
A
B
C
D
E
F
G
H

Pl. LIX.

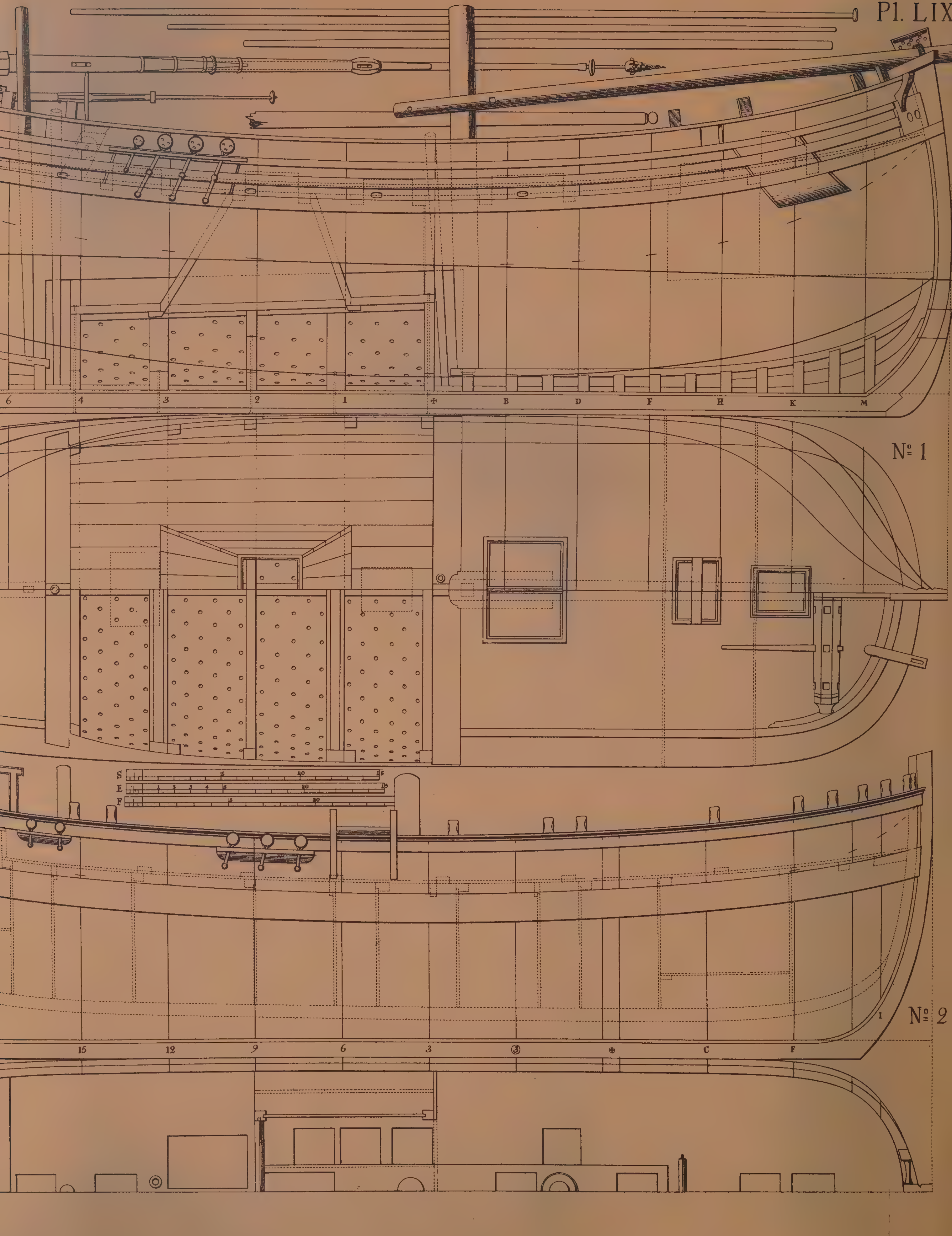


PLATE LIX

No 1	*Dutch dogger for carrying lobster (Fishing vessels)*	
	Length between perpendiculars	64 1/2ft
	Breadth moulded	19ft
	Draught	9ft

Note:

No. 1 is a Dutch lobster dogger with frames for the purpose.

No 2	*English herring buss (Fishing vessels)*	
	Length between perpendiculars	67 2/3ft
	Breadth moulded	16 2/3ft
	Draught	9ft

No 3	*English smack for flatfish (Fishing vessels)*	
	Length between perpendiculars	39 1/4ft
	Breadth moulded	13 2/3ft
	Draught	6 1/2ft

PLATE LX

No 4 *Large sumpar from Stockholm (Fishing vessels)*

Length between perpendiculars	44ft
Breadth moulded	13 1/2ft
Draught	4 1/2ft

Note:

No. 4 is a large fishing boat from Stockholm with a well in which 150 lisponds of fish can be carried.

No 5 *Sumpar from Stockholm (Fishing vessels)*

Length between perpendiculars	18 1/4ft
Breadth moulded	6ft
Draught	2 7/12ft

Note:

No. 5 is the same sort of boat as No 4, but smaller.

No 6 *English cutter (Vessels of war)*

Length between perpendiculars	55 1/2ft
Breadth moulded	23ft
Draught	11ft
Guns	12 3-pounders on deck
Swivel guns	14
Pairs of oars	5

Note:

No. 6 is an English cutter used in the English Channel both in an illicit trade and as well by the excise men. They are also sometimes used as fighting ships, as they are fast and excellent sailers.

No 7 *Dutch hoy with two masts (Merchant ships or vessels)*

Length between perpendiculars	84 5/6ft
Breadth moulded	23 1/4ft
Draught	9 1/2ft

No 8 *French felucca with 10 pairs of oars (Merchant ships or vessels)*

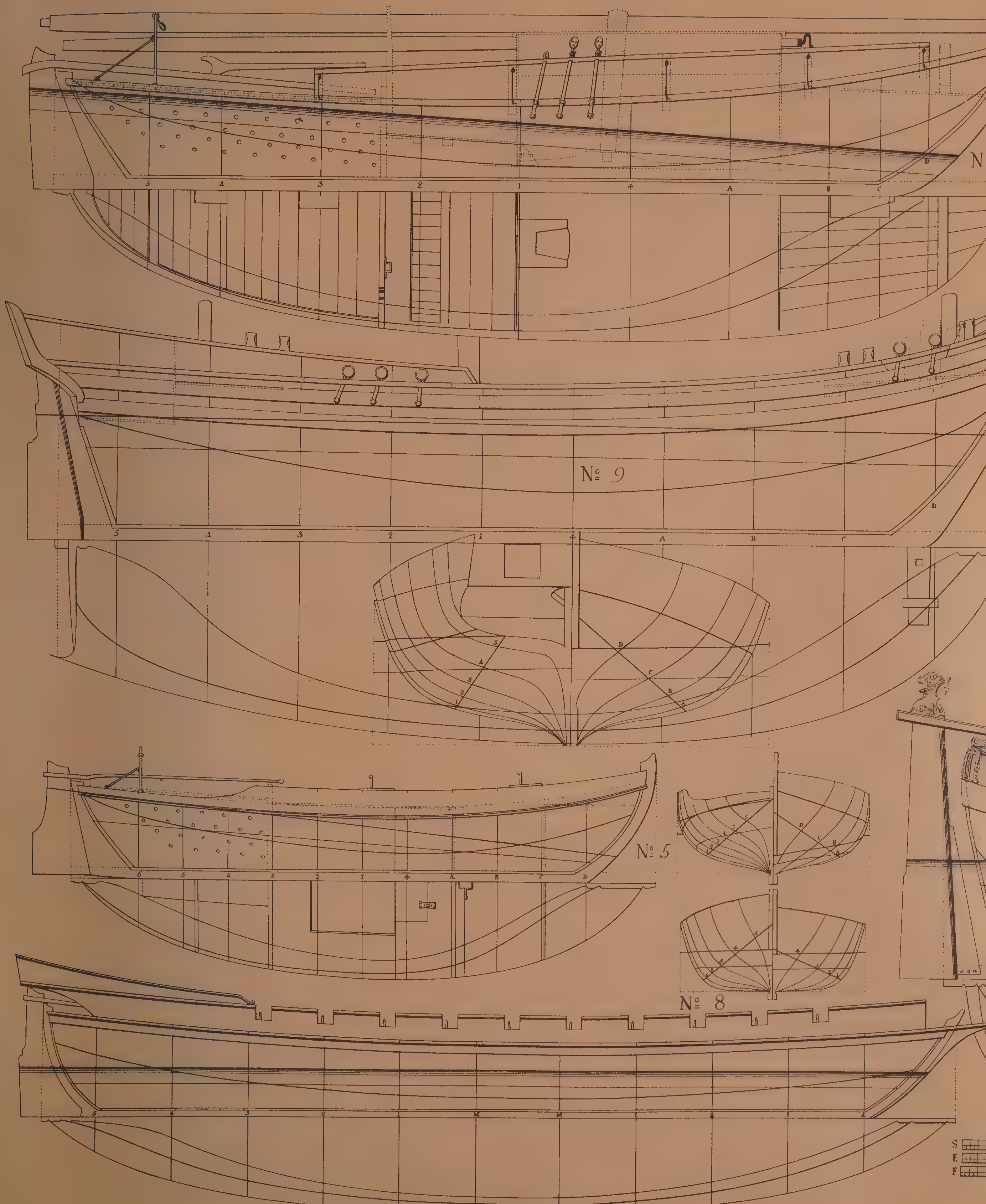
Length between perpendiculars	43 5/6ft
Breadth moulded	8 5/6ft
Draught	2 7/12ft

No 9 *A scoote used by the Finlanders (Merchant ships or vessels)*

Length between perpendiculars	64ft
Breadth moulded	25 5/6ft
Draught	8ft

Note:

No. 9 is a scoote used by the Finlanders to carry firewood to Stockholm.


N
№ 9
№ 5
№ 8
S
E
F

Pl. LXI.

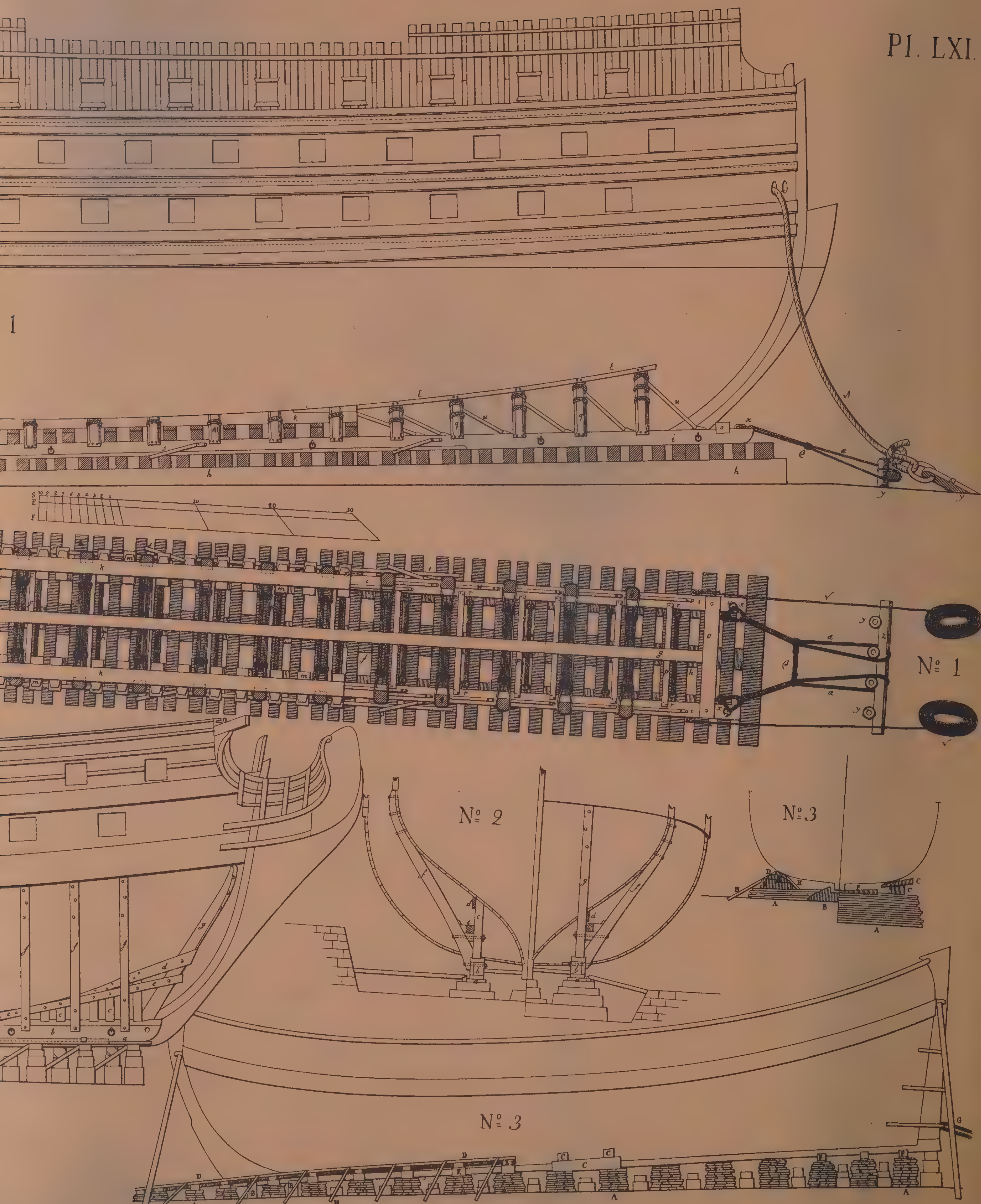


PLATE LXI

Three different methods of launching ship:
No 1 the French,
No 2 the English and
No 3 the Dutch.

No 1 shows the arrangements for the launching of the 112-gun ship of the line *Royal Louis*, built in 1692 in Toulon with a length from stem to sternpost of 193ft, a breadth of 52 1/2ft and a draught of 28 1/3ft (Swedish feet). The figure shows how far construction had advanced by the time when she was launched. This method is still used by the royal yards.

aa), bb) the standing way: cc), dd) broad blocks laid between the frames of the standing way; ff) the sliding plank; gg) the keel of the ship; hh) frames of the standing way; ii) bilge-way or cradle which slides over the frames of the standing way; kk) stoppings up which support the ship on the bilge-way; ll) wooden chocks between the bilgeway and the stoppings up; mm) wedges holding stoppings up kk) fast under the bilge; nn) vertical bevelled pieces outside the shores and poppets to which the lashings are made fast; oo) cross-pieces holding the ends of the bilge-way together; pp) struts between the bilge-way and the sides of the keel; qq) baulks shoreing up the ends of the ship; they are attached at the top to the ship and at the bottom to the bilge-way; $\varepsilon\varepsilon$) dagger planks to hold the ends of the baulks qq); rr) lashings which pass from one side of the bilge-way to the other, under the keel; ss) dog shores which are knocked away when the ship is launched; tt) ribbands fastened to the standing way frames outside the bilge-way; uu) props which support the baulks qq); ww) shores to be knocked away before dog shores ss) are released: $\varkappa$, α and β are holding warps to be cut when the ship is launched; rr) lashings that hold the bilge-way under the ship after launching; δ) anchor cable to hold the ship after she has slid into the water.

No 2 shows the English method of launching men-of-war. This is almost the same as the Swedish method.

aa) sliding plank on which the bilge-way runs; bb) the bilge-way, constructed under the ship; cc) poppets which stand on the bilge-way and support the ends of the ship; dd) dagger planks which hold the upper ends of the poppets; ff) shores which are fastened to the ship and to the bilge-way; ee) daggers between the shores and poppets cc) to prevent them from coming away from the sides of the ship; gg) shores which run forward from the bilge-way to under the cut-water which prevent the ship from sliding backwards in the bilge-way; hh) shores which fall away when the ship is launched.

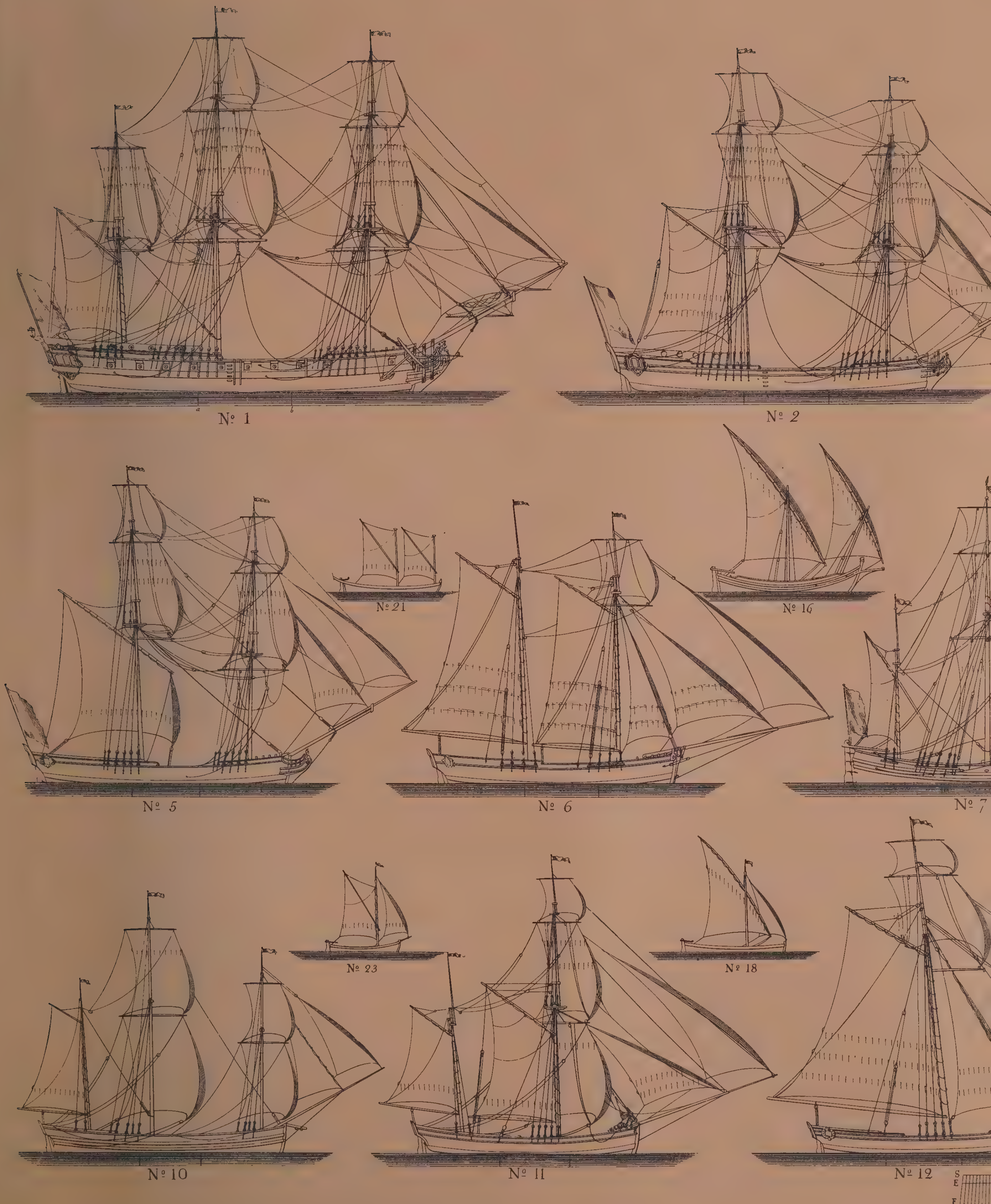
No 3 shows the method used by the Dutch to launch large and small vessels and even East Indiamen. AA) is a surface formed of thin planks which fill in the space between the ground, the standing way and the keel; BB) are two blocks which are rabbetted to take the keel; C) is a block fastened to the standing way A); between this block and the bilge are two wedges which hold the ship before launching; DD) is a strong plank laid at an angle, which prevents the ship from capsizing when she is launched; EE) are wooden chocks which support this plank; FF) are wedges which are rammed in when the ship is launched. The upper surface of these wedges, the bottom of the keel, the two blocks BB), the rabbet under the keel and the two planks DD) are all well smeared with tallow. HH) are small props which support planks DD) on either side. G) is part of a rope which passes through the lowest rudder googing or gudgeon and is made fast to a bollard or an anchor on land, and which is cut when wedges F) are rammed in, while at the same time wedges CC) are knocked away.

PLATE LXII

Plate LXII shows different sorts of vessels and rigging; the greatest number of these manners of rigging are peculiar to the various vessels. The breadth of the vessel is shown by the two small vertical lines—marked a and b in figure No 1.

The yards have been drawn at an angle of 60° to the midship line of the vessel along the keel; thus the length of each yard is more than twice that shown in the figures. All the rigging plans have been drawn to the scale on the plate.

No 1 Frigate or ship's rigging
No 2 Snow
No 3 Ketch
No 4 Brig
No 5 Bilander
No 6 Schooner
No 7 Dogger
No 8 Dutch Hoy
No 9 Galeass used in the Baltick
No 10 Kray used in Finland
No 11 Ketch-yacht used in the Baltick
No 12 Sloop
No 13 Dutch Tjalk
No 14 English Hoy
No 15 English Cutter
No 16 Tartane with lateen sails
No 17 Pleasure boat or yacht
No 18 French Longboat with a lateen sail
No 19 Swedish Longboat
No 20 English Deal Cutter with three spritsails
No 21 Pinnace with two spritsails
No 22 Fishing boat on the coast of Brittany
No 23 Yawl with spritsail and fore-staysail
No 24 Yawl used by the pilots at Stockholm


№ 1
№ 2
№ 21
№ 16
№ 5
№ 6
№ 7
№ 23
№ 18
№ 10
№ 11
№ 12
S
E
F

Author's Preface to the
»Tractat om Skepps-Byggeriet« 1775

On the resistance which a ship in motion meets from the water

On the dimensions of ships

On the proportions of privateers

On the proportions of masts and yards for merchant ships

On the construction of the scale of solidity

On the measurement for tonnage and stowage

On the accommodations for provisions

The Author's Preface

If we were to take a view of the immense number of ships that have been built, since mankind first began to navigate upon the ocean, and note all the different steps, which have been taken in improving their construction, we should at first sight be inclined to believe, that the art of ship-building had, at length, been brought to the utmost perfection. An opinion that would receive additional force from a consideration of the few essential alterations, which have been introduced either in their form or rigging, during our own age.

Yet when we recollect the different kinds of ships and vessels, that are used in Europa, it will appear less surprising to us, if there should be good grounds for asserting that their very great variety, equally with other causes, have prevented ship-builders and riggers from discovering either the true figure and shape of ships, or the best mode of rigging them, either generally, or, for each species of vessel in particular.

In order to form a decisive opinion in both these points of view, on the degree of perfection to which ships in general have arrived, we will divide those of all nations into two classes; comprising in one, all small vessels, or those used in short voyages and narrow waters; in the other, all larger ships, or those employed in distant voyages, and calculated for going out to sea.

The first class consists of the vessels, that different natives make use of in their coasting trade, or in their commerce with neighbouring countries. As the climate, the extent and depth of the seas, the position of the countries with respect to the sea and to each other, also their productions, are different in different countries, the proportion and form of these vessels, as well as the mode of rigging them, must necessarily depend upon these circumstances. Thus a species of perfection may be found in the circumstance, that they are dissimilar in the same degree as their objects differ.

On the contrary, if we consider the ships comprehended in the second class, even though of different countries, we shall find that being built for the same purposes, they are similar in their essential parts. As to their proportions, we find that the breadth is between one-third and one-fourth of the length; that the least have usually greater breadth in proportion to their length than the largest; that the draught of water is something greater or less than the half breadth. The height out of the water has also limits, which depend on the particular destination of the ship. The accommodations, moreover, in these ships, among all nations have a great similarity; they differ only in matters of small importance, in which each follows the plan that appears most convenient.

With respect to form, we see that all ships have their greatest breadth a little before the middle; that they are leaner aft than forward; that those designed for ships of burthen are fuller in the bottom; that those built for sailing are leaner there; that the stem and stern-post have a rake; that they have a greater draught of water aft than forward, &c. With regard to the rigging, most vessels have three masts, others two, and some only one; which depends on their size. These masts with respect to the ships and the manner of rigging them, have nearly the same proportions and the same place. They are also generally rigged in the same manner, except that some may have more or less sail, according to the judgment of the owner. All ships have their center of gravity a little before the middle of their length, and the center of gravity of the sails always before the center of gravity of the ship.

In this manner all ships designed for navigating in the open sea are constructed; and as this mode of construction is the result of an infinite number of trials and experiments, and of alterations made in consequence thereof, it would be improper to infringe on limits so established.

But although ships are thus confined as to their proportions, within certain limits, still however they admit of such variations in their form, as to produce an infinite number of qualities more or less good, or more or less bad.

There are ships possessing all the qualities, which we can reasonably wish for, and there are others, which, although within the abovementioned limits, have nevertheless a great many faults.

In the construction of ships, people usually make attempts at different times to improve the form, each person according to his own experience; thus after the construction of one ship, which has been tried and found to possess such or such a bad quality, it seems possible to remedy this defect in another. But it often (not to say generally) happens, that the new ship possesses some fault equally as great, and frequently even that the former defect, instead of being removed, is increased. And we are unable to determine, whether this fault proceeds from the fault of the ship, or from other unknown circumstances.

It thus appears, that the construction of a ship with more or less good qualities, is a matter of chance and not of previous design, and it hence follows, that as long as we are without a good theory on shipbuilding, and have nothing to trust to beyond bare experiments and trials, this art cannot be expected to acquire any greater perfection, than it possesses at present.

It becomes a matter of importance then, to discover what may bring this knowledge to greater perfection. Seeing that ships, the proportions of which lie within the same limits, nay, which have the same form, differ greatly from each other in respect to their qualities, and even that with a small alteration in the form, a ship acquires a quality immediately opposite to the one we wish to give it, we must conclude that this arises from certain physical causes; and that the art of constructing ships cannot be carried to greater perfection, till a theory has been discovered, which elucidates these causes.

In every art or science there exists a hidden theory, which is the more or less difficult to be found out, as the art or science depends more or less on physical causes.

Into the theory of a common oar, even Archimedes made researches, and many others after him; notwithstanding which, this theory is not yet fully explained. If such difficulties occur in this investigation, how great must those be which attend the theory of ship-building, where so many other circumstances are combined!

It is true, that the oar is made use of to great advantage in rowing, the cannon in firing; an infinite number of machines are in like manner used, without considering it absolutely necessary to investigate to the bottom their theory. We see how little these machines can be advanced towards perfection by its assistance. The question may be perhaps concerning some inches more or less in the length of the oar, concerning a twentieth part less matter for a cannon of the same force; so that the theory for these objects is not so necessary as for ships.

For ships, we have to fear an infinity of bad qualities of the greatest consequence, which we are never sure of being able to remove, without understanding the theory.

At the same time the construction of ships and their equipment, are attended with too great expense, not to endeavour beforehand to insure their good qualities and their suitableness for what they are intended for. The theory then which elucidates the causes of these different qualities, which determines whether the defects of a ship proceed from its form, or from other causes, is truly important; but as the theory is unlimited, practice must determine its limits. We may consequently farther conclude, that the art of ship-building can never be carried to the last degree of perfection, nor all possible good qualities be given to ships, before we at the same time possess in the most perfect degree possible, a knowledge both of the theory and practice.

To possess this theory in all its extent seems to exceed the force of the human understanding. We are obliged therefore to content ourselves with a part of this vast science; that is, with knowing sufficient of it to give to ships the principal good qualities, which I conceive to be:

1. That a ship with a certain draught of water, should be able to contain and carry a determinate lading.
2. That it should have a sufficient and also determinate stability.
3. That it should be easy at sea, or its rolling and pitching not too quick.
4. That it should sail well before the wind, and close to the wind, and work well to windward.
5. That it should not be too ardent, and yet come easily about.

Of these qualities one part is at variance with another; it is necessary therefore to try so to unite theory and practice, that no more is lost in one object than is necessary in order to secure another, so that the sum of both may be a maximum.

This is the subject of this short treatise. Whether I have succeeded or not, will be seen by the reader. There will be found in it some things both in theory and practice, which have not hitherto been treated of, and which may be worthy of the attention of persons who are desirous of applying themselves to this science; it will be seen moreover, that the principles laid down admit of demonstration, although they are of the most difficult nature.

Still however it must be confessed, that this science has one great difficulty, in which it probably differs from all others; namely, that even after following the theory with the greatest exactness, and executing the work, according to its rules, with the greatest care, the constructor may notwithstanding suffer in point of professional reputation. For although a ship may have been built in conformity with all the rules which both theory and practice prescribe, its yards have got their true proportions, and the masts their true place and position; so that there appears to be the greatest certainty of its possessing all the best qualities; it may nevertheless happen, that such a vessel will answer very ill for the following reasons:

1. Although the rigging of the ship (when the masts and yards are put in their place, and are in due proportion) is not a matter of such great difficulty, but that every seaman knows how to give the proper proportions, it happens, notwithstanding, that too stout cordage and too large pullies are frequently used, which renders the weights aloft too considerable. It may happen also that the sails are badly cut, on which account the ship may lose the advantage of sailing well close to the wind, of coming about, &c. whence great inconveniences may result, with which the form of the ship has nothing to do.
2. The ship is liable also to become ungovernable, to lose its good qualities in every way by the bad disposition of the stowage. If the lading be too low, the moment of stability will become too great, which will occasion violent

rolling. On the contrary, if the weight of the lading be too much raised, the ship will not carry sail well when the wind blows fresh; neither will it be able to work off a lee shore; if the lading be too heavy towards the extremities, it will produce heavy sending and pitching, whence the ship may become the worst possible sailer, with other inconveniences which are not the fault of the ship itself.

3. The good performance of a ship depends also on the manner in which it is worked; for if the sails be not well set, with respect to the direction of the wind and the course, it will lose in point of sailing; it will become slack so as to miss stays, which often places a ship in a critical situation. The person who works the ship is also charged with an attention to the draught of water; and to the manner of setting up the shrouds and stays, upon which the qualities of the ship greatly depend. Furthermore, to work the ship well is of greater consequence in a privateer, than in a merchant ship. One who understands the management of his ship, knows how to give it all the good qualities it is capable of; he knows how to employ those qualities to his advantage, and when he is engaged with an enemy, he thereby makes himself master of the attack; but he who blunders in the working of his ship, may thereby not only be reduced to the necessity of acting solely on the defensive, but seldom if ever escapes falling an easy prey to the enemy, although his ship is ever so carefully and well built.

Thus an owner may suffer considerable losses, in a thousand ways, less through the defects of his ship, than the ignorance of the commander.

It is even frequently observed, that a ship exhibits the best qualities, during one cruise, and the very worst during another.

Lastly, it is evident from all that has been said, that a ship of the best form, will not shew its good qualities, except it is at the same time well rigged, well stowed, and well worked by those who command it.

On the resistance which a ship in motion meets with from the water

When a ship is at rest, the pressure of the water upon each of its extremities is the same; but as soon as it is impelled by any force, the pressure is increased at the end opposite to the impulse, and is diminished at that end where it acts: this we shall explain hereafter.

If a plane is moved in the water, the resistance is the most forcible, when the direction of motion is perpendicular to the plane, and becomes less if the plane assumes a position oblique to the line of motion.

Thus bodies of different forms and convexities, with equal bases, experience different resistances.

It is by no means difficult to express the resistance, which one body meets with in striking another: but it is not equally easy to express the effect which a medium produces on bodies, which are moved therein. The effect of the impact of bodies on each other is subject to known mechanical laws, but that of mediums upon bodies depends on physical causes, with which we are unacquainted.

To surmount this difficulty, fluids have been supposed to consist of globular particles, infinitely small, which follow each other very closely, and strike the body in succession; as for example:

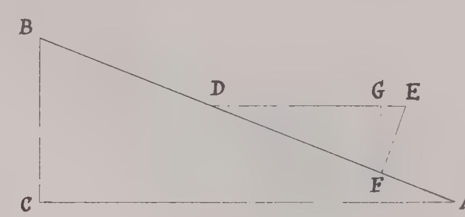


Fig. 11

Let ABC (Fig. 11) be a right-angled triangle, suppose the fluid, or a particle of the fluid, to strike the side AB of this triangle in a direction parallel to AC, from A to C, with the velocity ED.

If ED denote the perpendicular resistance against the base BC, it may be resolved into two others, EF perpendicular and FD parallel to AD; as the effect in the direction FD is nothing, inasmuch as the fluid glides along AB, therefore EF alone acts on the triangle, and in a direction perpendicular to AB; in like manner this force may be resolved into two others, GF perpendicular and EG parallel to AC; GF is the lateral force, which impels the triangle from B to C, but EG denotes the direct force, which acts on the side AB, and consequently the resistance: thus the absolute or perpendicular resistance at the point D is to the relative resistance as ED to EG; but $DE:EG::DE^2:EF^2$; and since the number of particles, which can strike the side AB in the direction ED are in proportion to BC, and from similar triangles DEF, ABC we have $DE:EF::AB:BC$, the direct resistance against the whole triangle is as $\frac{BC^2}{AB^2} \times BC$.

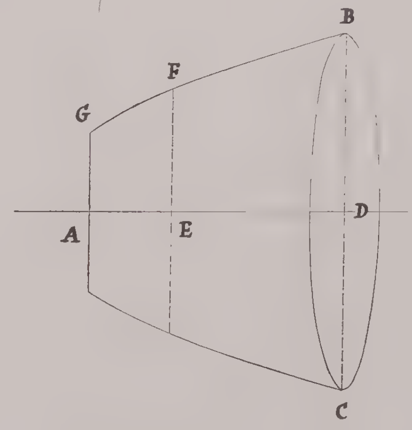


Fig. 12

Upon this principle the known curve GFB (Fig. 12) of least resistance has been investigated, which is of such a nature, that by revolving round its axis AD it generates a solid $AGBD$, which experiences less resistance from the water than any body whatever of the same length AD and the same base BC. As this problem is treated on by several authors, I shall here only give the construction of the curve.

If $AE = x$, $EF = y$, the equation will be $y\dot{y}^3\dot{x} = a \times (\dot{x}^2 = \dot{y}^2)^2$ (see Simpson's Fluxions, Art. 413.).

The angle *AGF* has been found to be a right angle and a half, or 135°. Let $v = \frac{\dot{x}}{\dot{y}}$; then $\dot{x} = v \times \dot{y}$, and $\dot{x}^2 = v^2 \times \dot{y}^2$. Substituting the value of $\dot{x}^2$ in the equation, we have $vy\dot{y}^4 = a \times (v^2\dot{y}^2 + \dot{y}^2)^2$, or $vy = a \times (v^4 + 2\,v^2 + 1)$; hence $y = a \times \left(v^3 + 2\,v + \frac{1}{v}\right)$ and $\dot{y} = a \times \left(3\,v^2\dot{v} + 2\,\dot{v} - \frac{\dot{v}}{v^2}\right)$ and therefore $\dot{x} = a \times \left(3\,v^3\dot{v} + 2v\dot{v} - \frac{\dot{v}}{v}\right)$ of which the fluent or $x = a \times \left(\frac{3}{4}v^4 + v^2 - \log.\, v\right) + C$. When $v = 1$, then $x = 0$ by the above-mentioned property, whence $\frac{7}{4}a + C = 0$, and $C = -\frac{7}{4}a$; hence $x = a \times \left(\frac{3}{4}v^4 + v^2 - \frac{7}{4} - \log.\, v\right)$. Supposing $a = 1$, the least ordinate *AG* will be equal to 4. If, beginning with 1, we give successive values to v, and substitute them in the equation of x and y, we shall have the following values of x and y.

$v = 1{,}0$	$x = 0$ $y = 4$	$v = 1{,}06$	$x = 0{,}262$ $y = 4{,}254$	$v = 1{,}1$	$x = 0{,}453$ $y = 4{,}440$
$v = 1{,}2$	$x = 1{,}053$ $y = 4{,}961$	$v = 1{,}3$	$x = 1{,}820$ $y = 5{,}566$	$v = 1{,}4$	$x = 2{,}655$ $y = 6{,}258$
$v = 1{,}5$	$x = 3{,}892$ $y = 7{,}042$	$v = 1{,}6$	$x = 5{,}255$ $y = 7{,}921$	$v = 1{,}7$	$x = 6{,}873$ $y = 8{,}901$
$v = 1{,}8$	$x = 8{,}775$ $y = 9{,}987$	$v = 2{,}0$	$x = 13{,}557$ $y = 12{,}500$	$v = 2{,}2$	$x = 19{,}900$ $y = 15{,}502$

Fig. 13

Let $AE = x$, $EF = y$ (Fig. 13); then from *A* the values of x are set off on *AD*, and on the corresponding ordinates *AG*, *EF*, &c. the values of y, we shall have the line *GFB*, which as we have said, by revolving round its axis *AD*, will generate a solid, which will experience less resistance than any other body of the same length *AD*, and of the same base *BD*. If this solid be terminated by a cone *AHG* whose base = *AG*, the resistance by that means will be considerably diminished.

We shall see by the following Articles the quantity of resistance, which a body like this meets with from the fluid.

When a body is at rest in the water, it receives a pressure at every point of the part immersed, which is perpendicular to its surface, and its force proportional to the depth of the part pressed.

This is a fact derived from experience, which it is necessary not to lose sight of: but before we go farther into the investigation of the expression for the resistance, which a body meets with when impelled through a fluid, it is necessary to notice the circumstances which occur, when a ship sails forward, or when a ship by means of any force whatever is drawn through the water.

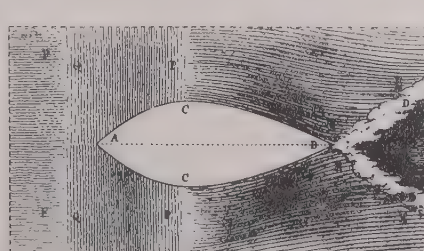


Fig. 14

When a ship ABC (Fig. 14) is put in motion in still water with any velocity, it always happens that the water upon the extremity A before the greatest breadth C, rises against this part above the surface F. This elevation is perceptible to some distance before the ship in the direction of its course; it also extends laterally towards PQ; but past the greatest breadth C, the water falls again, so that between C and B it is below its proper level, until it meets in D the part of the fluid, which constantly follows the ship with the same velocity as the ship has itself, in order to fill up the void space, which it would leave behind. But as the water, which glides along the side of the ship, has already filled this space, there is a collision of this fluid in EE, which produces what is called eddy water. This is a thing remarked more in small vessels, which draw little water; but in great vessels, the elevation of the water afore is not perceptible till they have attained a velocity of 4 or 5 feet in a second. This water, which is before the greatest breadth, is driven forward with the ship, and so moves in the same direction; and as it is higher afore the greatest breadth than abaft, it flows down a declivity, so as to acquire a velocity in a direction contrary to that of the ship; and the greater velocity the ship has, the greater is this declivity.

All this is sufficiently observable, when a ship is navigated in a sea little agitated, where there are no waves: but when a ship sails or is drawn along a channel, where there is not more than three or four times the breadth of the ship between it and the side of the channel, this effect is much more perceptible, however small may be the velocity.

There necessarily results from what we have just observed; first, that the resistance a ship sailing with a given velocity meets with, is increased on account of the water's rising before the greatest breadth, and because the ship has to propel a more elevated body of water before it, than at the commencement of its motion; although this column thus elevated and driven a-head, by acting on the water in the direction of its motion, before the body of the ship gets to the same point, in some degree diminishes the resistance. Secondly, that the resistance is farther increased, because the water is lower behind the greatest breadth, and because this water has, moreover, lost in regard to its pressure against the after part of the ship, a force which depends on the velocity of the ship, and also on that with which the fluid flows along the after parts of the ship, in running from the greatest breadth of the ship to the stern-post.

After the observations and remarks which have been made, let us form an equation, which expresses the resistance that a body meets with when impelled through the water.

A difficulty occurs however, which arises from the circumstance of its being necessary to compare the pressure of the water with the effect arising from the velocity of the body, two forces, which are of very different kinds. But since we may neglect in the expression the perpendicular pressure of the water against the surface of the ship when at rest (the effect being the same, whatever be the extremity of the body that moves forward), we may observe that the force in question expresses only the effect of the inequality of the pressure on the two extremities of the ship during the motion, or the resistance, which is thereby occasioned, and which depends as to its amount on the velocity of the ship.

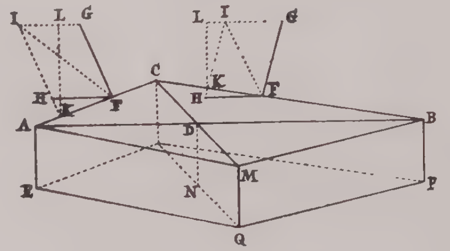


Fig. 15

Let $ACBQ$ (Fig. 15) be formed of two wedges joined together at their base CQ; let the pressure of the water, perpendicular to the surface in every point, be denoted by FG, FG.

Suppose this body to be moved with the velocity FH in a direction parallel to the middle line AB, from B to A; complete in the usual manner the parallelogram $FGIH$, and draw the diagonal IF. Then we have the resultant of this velocity with the pressure of the water in the direction IF. If from the point K, where the line IH meets the line AC or CB, we draw the line KL perpendicular to GI, IL will be the resistance, which the body experiences in the direction BA, and LI is a force on the hinder part of the body CB, which impels it forward in the direction in which it moves.

Let CM be perpendicular to AB; $CD = DM$, and DN be perpendicular to the surface $ACBM$. Let $FG = m$, $FH = n$; the area of the plane $CE = A$, the area of the plane $CP = B$, and lastly the area of the plane $CN = C$.

From the similar triangles ACD, FHK, KIL, we have $KH = \frac{DC}{AC} \times n$, and hence $IK = \frac{DC}{AC} \times n + m$, and also $IL = \frac{DC}{AC} \times \left(m + \frac{DC}{AC} \times n\right)$. IL represents the resistance at the point F, which is produced by the forces FG (m),

HF (n). But the number of pressures FG is to the number of pressures FH, as the area A is to the area C; consequently $A \times \frac{DC}{AC} \times m + C \times \frac{DC^2}{AC^2} \times n$ represents the effect of the water on the forepart. In the same manner we get $B \times \frac{DC}{BC} \times m - C \times \frac{DC^2}{BC^2} \times n$ for the effect of the water on the aft part.

Subtracting this last expression from the first, the resistance against this body moved in the direction AB, will be expressed by $A \times \frac{DC}{AC} \times m + C \times \frac{DC^2}{AC^2} \times n - B \times \frac{DC}{BC} \times m + C \times \frac{DC^2}{BC^2} \times n$, and as $A \times \frac{DC}{AC} \times m = B \times \frac{DC}{BC} \times m$, the expression for the resistance is reduced to $C \times \frac{DC^2}{AC^2} \times n + C \times \frac{DC^2}{BC^2} \times n$; whence we see, so long as the velocity is not sufficient to produce an elevation of the water afore, and a depression abaft the greatest breadth, so as to increase the fore resistance and diminish that aft, that the body will experience the same resistance, whether the sharp or obtuse extremity moves forward; and yet that the resistance will be the least when the two extremities are equal, or what is the same thing, when the greatest breadth CM is in the middle.

But if we suppose that the water runs a-head of the ship before its greatest breadth with a velocity v, and that it has acquired a velocity w in a direction opposite to that of the body abaft this greatest breadth, then the velocity forward $= n - v$, and aft $= n + w$; and as the resistance is in proportion to the squares of the velocities, it will be expressed definitively by $C' \times \frac{DC^2}{AC^2} \times (n - v)^2 + C \times \frac{DC^2}{BC^2} \times (n + w)^2$, where we suppose C' to be greater than C, inasmuch as the water before the greatest breadth is more elevated than behind it.

Hence it is seen, whatever proportion there is between n, v, and w, the body meets with less resistance, when the obtuse end is forward, than when the acute end is forward; and that it depends on the quantities $n - v$, and $n + w$, how far the main breadth should be before the middle point, so that the resistance may be less, than if its situation were anywhere else.

We see also that the greater v and w are with respect to n, the more the greatest breadth should be carried before the middle to render the resistance least.

It never can happen that $v = n$, for in this case, the water, would run forward with the same velocity as the ship, which is not possible. v is very small with respect to n, when the velocity is little; so that when n is very small $v = 0$. It is the same also in respect to the water abaft the greatest breadth; when the velocity is small and the body has its greatest breadth very far aft, the water follows the body to fill up the void space which it leaves; from which cause a part of the water follows the same direction as the body, so that the velocity of the body in relation to the water is $n - w$, whence it follows that the expression for the resistance ought to have this form

$$C' \times \frac{DC^2}{AC^2} \times (n - v)^2 + C \times \frac{DC^2}{BC^2} \times (n \pm w)^2.$$

If this expression for the resistance be not exact, at least what results from it is confirmed by the following experiments.

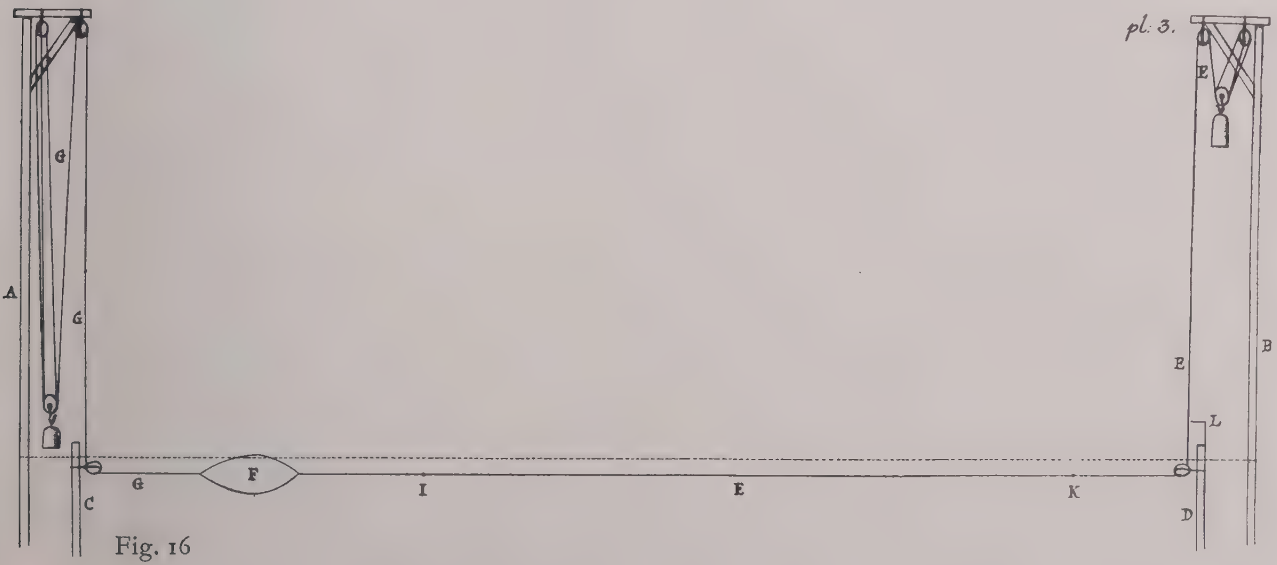
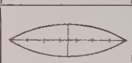
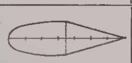
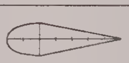
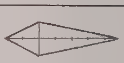
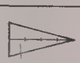


Fig. 16

In a large and deep pond (Fig. 16) were placed a hundred feet from each other two poles *A*, *B*, and two piles *C*, *D*, to which were fitted two copper pullies, and through these were reeved ropes to support the weights; the whole as is represented in the figure. The lines *E* and *G* were attached to the body used in the experiment. On the line *E* a weight was placed, to give motion to the body in the water, and on the other line *G* there was also a weight, but less than the first, to keep the body in a straight line from which it would have deviated without it; to the line *E* were tied two small pieces of red cloth *I*, *K*, at the distance of 74 feet from each other. To measure the time a stop-watch shewing seconds was used. When the mark arrived at *L* the stop-watch was let go, and when the mark *I* was come to the same point, the watch was stopped. It then shewed the number of seconds which the body *F* took up to pass over the space of 74 feet. The bodies, on which the experiments were made, were of wood, and were 28 inches in length; the transverse sections under the water were circular. Their diameters at the greatest breadth were 2/7 of the length, or 8 inches; the water-lines were either straight or conic parabolas, and the vertex of the parabolic line was at the greatest breadth. As these bodies were lighter than water, lead was run in, until their specific gravity was nearly equal to that of sea water, so that they only just floated, having their axes parallel to the surface of the water. The weight on the line *E* to put the body in motion, was varied according as it was required to increase or diminish the velocity; but the retarding weight was always the same. The bodies N°. 1, 2, and 3 had the same weight, but the others were lighter in proportion as the solidity of a cone is less than that of a paraboloid.

Weight of the bodies		N°. 1 27 pounds	N°. 2 27 pounds		N°. 3 27 pounds		N°. 4 22 pounds		N°. 5 19 3/4 pounds		N°. 6 16 3/4 pounds		N°. 7 12 pounds	
Form of the bodies		 *A* *A*	 *B* *C*		 *D* *E*		 *F* *G*		 *H* *I*		 *O* *P*		 *R* *P*	
Moving weights	Retarding weights	Time the bodies have been describing the space of 74 feet, in seconds												
		Seconds *A*	Seconds *B*	*C*	Seconds *D*	*E*	Seconds *F*	*G*	Seconds *H*	*I*	Seconds *O*	*P*	Seconds *R*	*P*
3/4 the weight of the body	1/2 the weight of the body	25 1/2	26 1/4	24 3/4	27 3/4	26 1/2	25 3/4	25 1/2	27 1/4	24 1/4	30	29 3/4	45	29 1/2
The weight of the body	1/2 the weight of the body	14	14	14 1/2	14 1/2	16 1/2	13 3/4	13 3/4	15	16	24 1/2	24 1/4	38	24
1 1/2 weight of the body	1/2 the weight of the body	11	10 1/2	11 1/2	10 1/2	13 1/2	11	11	10 1/4	11 1/2	12 1/2	17 1/2	30 3/4	19 1/4
37 pounds in all	12 lb. and 1/3 in all	12 1/2	lost		11	14	10 3/4	11	10	11 1/4	12	16	—	—

The bodies N°. 1. has its greatest breadth at the middle, and its two extremities formed by parabolic lines.

N°. 2. has its greatest breadth at 2/7 of its length from the point *B*; the two extremities are also parabolic.

N°. 3. has its greatest breadth 1/7 of the length from the point *D*; the two extremities still parabolic.

N°. 4. has its greatest breadth at the middle; the extremity *F* parabolic, the other *G* conic.

N°. 5. has its greatest breadth 2/7 of the length from the point *H*; the extremity *H* parabolic, the other *I* conic.

N°. 6. has its greatest breadth 2/7 of the length from *O*; the two extremities conic.

N°. 7. wholly conic, having the greatest breadth equal to that of the other bodies, and its length twice and an half the breadth.

To understand these experiments take N°. 2, where the moving weight is equal to that of the body, and the retarding weight is half of it. With the extremity *B* first, the body passes over 74 feet in 14 seconds; if on the contrary the extremity *C* be first, the body is 14 1/2 seconds in passing over the same space.

Each of these experiments was repeated six times, and a mean taken of the results, which for the most part were nearly equal; and where there was any difference, it did not exceed half a second. We do not find in the velocities, the proportions we are led to expect from a consideration of the weights; which arises from a motion produced at the surface of the water by a division of the fluid too near the surface. The number of pullies over which the line passes, renders the experiments less exact on account of friction. But as the friction is equal for all the experiments, the variation of velocity ought to be of the same kind.

The inferences which we may draw from all this are; first, that when the motion is slow, the body has greater velocity when the sharp end is forward than when the full; secondly, that when the velocity is increased to a certain degree, the body passes over the same distance in equal times, with either extremity forward; thirdly, that when the velocity becomes still greater, the body is less time in passing over the same distance, when the obtuse end is forward. Thus it is the velocity of the body which should determine the place of the greatest breadth, to render the resistance least.

M. Camus, in his Treatise on Moving Forces, speaks of experiments which he made to determine this point. We find likewise (Murray's Treatise on Ship-building) some experiments, which agree with the above sufficiently well; differing however from them in this, that whether the velocity is great or little, the body always experiences less resistance when the fullest end is forward, a circumstance which arises from the experiments having been made in a canal formed on purpose, in proportion to the breadth of which that of the body was considerable; so that the water could not pass it without rising before, and consequently being lower behind. This water must therefore have had a current on each side of the body, so that however slowly the body was moved in the canal, the effect of the water was the same, as when in the above experiments it was moved with the greatest velocity.

These experiments are agreable to the expression for the resistance which was given in the previous articles. The only question is to find the value of v and w relatively to n, and to see when we ought to employ the signs $+$ and $-$ in $n \pm w$. We know from what was previously said that the sign $-$ in $n \pm w$ is not to be used in the expression for the resistance, except when the velocity and the form behind the greatest breadth are such, that the water, which acts on the after part, moves in the same direction as the ship.

On the dimensions of ships

As we cannot conclude any thing from the last Articles concerning the proportions, which ought to take place between the length, breadth, and depth of the ship, and since its qualities depend greatly upon these proportions, it is necessary to enumerate those qualities, which are essential to a merchant ship; in order thence to determine the proportions most advantageous, and most likely to produce such or such qualities, which may be required.

A merchant ship ought:

1. To be able to carry a great lading in proportion to its size.
2. To sail well by the wind, in order to beat easily off a coast where it may be embayed, and also to come about well in a hollow sea.
3. To work with a crew small in number in proportion to its cargo.
4. To be able to sail with a small quantity of ballast.

To procure these advantages to a ship, it appears:

1. That to take a great lading with respect to its size, it ought to have great breadth and depth, in proportion to its length, and to be full in the bottom. Such a ship would also work with a small number of hands in proportion to its cargo. But it would neither sail well nor beat to wind-ward.
2. That to give the property of sailing and beating to windward, to the end that it might beat off a lee shore, as well as come about well in a hollow sea, the ship must necessarily have a considerable moment of stability in proportion to the plane of resistance, that it may be able to carry a press of sail, notwithstanding a strong wind; with this view is is necessary to give to the ship in question, great breadth in proportion to its length; to fill it much towards the

load water-line, curtailing it in the bottom. Such a ship would require a numerous crew because of the largeness of the sails, and the weight of its anchors.

3. That if it be required to navigate a ship with few men, in proportion to the lading, it should have a small surface of sails, and anchors of small weight. For this purpose it should have little breadth in proportion to its length.

It would also be enabled to carry a great lading, in proportion to its equipment of men, by giving it great fulness in its bottom; but such a ship would sail badly close to the wind, and would come about with difficulty in a hollow sea.

4. That to enable a ship to sail with a small quantity of ballast, it is necessary to fill the body between wind and water, when it has the ballast in; it should be large and little elevated above the water. A ship of this kind would carry a sufficient lading in proportion to its size, but it would ply badly when laden, especially if it were a large ship; without giving it a considerable quantity of sail, which would render it necessary to have a great number of men.

By this it is again proved, that we can conclude nothing concerning the length, breadth, and depth of ships, since different qualities require conditions diametrically opposite to each other. We may succeed in uniting two of these advantages by a certain form and by certain proportions given to ships, but it is impossible to combine all four in an eminent degree. It is not possible to gain on one side without losing on another.

Wherefore, for a merchant ship, it is necessary to combine these qualities, so that it may have the most possible of each. That is to say, that the expression representing the velocity and quantity of lading divided by the number of the crew and quantity of ballast, may be a *maximum*.

Again, however, as certain commercial speculations require one quality in preference to another; the nature of this commerce; the latitudes in which it is necessary to navigate; the ports for anchorage; all these must be considered in determining which of these qualities ought to prevail, without altering in any respect the size of the ship.

We must again observe that the qualities of similar ships vary in a different proportion from what a consideration of their size would give.

If the breadth be represented by the variable quantity B, the burden of the ship will vary in the proportion of B^3; the velocity of sailing $\frac{B^{1/2} \times L^{4/3}}{D^{3/2}}$ will vary as $B^{1/3}$, and the number of the crew, which is proportional to the area of the sails $B^2 L^{2/3}$, will vary in the proportion of $B^{8/3}$. So that, supposing two ships to be similar, the one of 320 lasts, and the other an eighth of this capacity or 40 lasts, whilst the larger will sail ten knots, the small one will only sail eight; and if the great one sail with a crew of twenty-four men, the small one will require four. According to the capacities of the two ships, it ought to be navigable by three men. Hence we see, that *in making small ships similar to large ones, the former will sail worse, and will require a more numerous crew in proportion to their capacities than the large ones.*

We have seen above, that we may obtain for a small ship a property of sailing equal to that of a large one, by increasing its moment of stability, and diminishing the plane of resistance; but as then it would have a greater quantity of sails, it would be necessary to increase the number of the crew.

It is possible to render a small ship navigable by a crew proportionate to its capacity, but it cannot be done without diminishing the quantity of canvass, and then the vessel will sail worse. One may remedy this fault to a certain point, by giving it less breadth; but we have seen that this would not be without inconvenience; so that upon the whole, we find that it is necessary to prefer, in small ships, the property of sailing well, to having it in our power to economise in the number of the crew.

The velocity being in proportion to $\frac{B^{1/2} L^{4/3}}{D^{3/2}}$, it increases as the depth decreases, supposing at the same time the length and breadth to increase. The object is attained more easily by adding to the length, but for the greatest safety of the navigation, in order that the ship overtaken by a squall may come to the wind, and that it may come about easily in a heavy sea, it is more convenient to increase its breadth, whence the metacenter will be more elevated; the sails may then have a greater surface; but once again, the ship would require a more numerous crew.

We see then, that *great and small ships cannot, with the same form, sail with the same security*, and that we cannot avoid the inconvenience of being obliged to have a more numerous crew in proportion in small ships; as in the place of four men, six, &c.

So that small ships cannot have the same advantages as large ones, when it is required to employ them in the same trade.

As small ships lose in the quality of sailing, by being of a form similar to that of large ones, also large ones would gain in this respect by being shaped like small ones; we may thence conclude that it is proper to give to large ships the same form which small ones have; since thereby they would gain in the quality of sailing. But for merchant ships, where it is so much the more necessary to give great capacities in the water, as they are the more large, and

as they seldom want a superior quality of sailing, provided they are sufficiently stiff upon a wind not to be embayed on a lee shore; considering besides, that these ships would lose the advantage of sailing with a small crew, and moreover, that a large ship costs more in its construction in proportion than a small one: for this kind of ships, I say, it is necessary to try to combine qualities the most advantageous to the interest of the owner.

All these inquiries do not bring us to the determination of the proportion to be given between the length, breadth, and depth of the ships, and we see that theory alone is not sufficient for this purpose: it becomes necessary therefore to introduce practice, and to see by several trials and various experiments, in what manner different ships answer in different cases. Then we may, by means of the above expressions, give to large or small ships the qualities which we wish, and carry them to a certain degree with relation to those of a known ship.

Species of ship	Burthen in lasts reduced into cubic feet, reckoning 91 cubic feet for each last	Displacement in cubic feet to the outside of the timbers	Length from the perpendicular at the stem to that at the sternpost	Greatest breadth to the outside of the timbers	Distances of the load water-line from the upper edge of the rabbet of the keel, at the frame (·)	Area of the midship section	Depth of the keel measured from the upper edge of the rabbet	Difference of draught of water
	P	D	x	z	h	$\oplus$	k	d
Frigates	$D^{17/18}$	$P^{18/17}$	$\overline{56\,D^{1/3}}$	$\frac{x^{4/5}}{1{,}383}$	$\frac{x}{8{,}1}$	$\frac{1{,}705\,D}{x^{1+1/40}}$	$\frac{x^{2/5}}{4{,}64}$	$\frac{x^{3/4}}{23{,}3}$
Heckboats or Pinks	$D^{19/20}$	$P^{20/19}$	$\overline{54\,D^{1/3}}$	$\frac{x^{4/5}}{1{,}429}$	$\frac{x^{1-1/60}}{7{,}547}$	$\frac{1{,}729\,D}{x^{1+1/27}}$	$\frac{x^{3/7}}{5{,}66}$	$\frac{x^{2/3}}{17{,}5}$
Cats or Barks	$D^{21/22}$	$P^{22/21}$	$\overline{52\,D^{1/3}}$	$\frac{x^{4/5}}{1{,}476}$	$\frac{x^{1-1/30}}{7{,}032}$	$\frac{1{,}76\,D}{x^{1+1/20}}$	$\frac{x^{1/2}}{8{,}4}$	$\frac{x^{2/3}}{18{,}8}$
Flat-bottomed Vessels, or Vessels with a small draught of water	$1{,}07\,D^{21/22}$	$\frac{P^{22/21}}{1{,}07}$	$\overline{63\,D^{1/3}}$	$\frac{x^{4/5}}{1{,}6}$	$\frac{x^{1-1/10}}{6{,}436}$	$\frac{2{,}1\,D}{x^{1+1/10}}$	$\frac{x^{1/2}}{9{,}8}$	$\frac{x^{2/3}}{24}$

Species of ship	Area of the load water-line	Quantity by which the center of gravity of the displacement is below the load water-line	$\int \frac{2}{3} \times \frac{y^3 \dot{x}}{D}$	Fraction of the distance between the center of gravity of displacement and the load water-line, which the center of gravity of the ship and lading is below the water	Distance of the metacenter from the center of gravity of the ship and lading	Moment of stability
	W	V	S		L	M
Frigates	$\frac{z x^{1+1/30}}{1{,}49}$	$\frac{x^{7/6}}{48}$	$\frac{x^{1/2}}{1{,}289}$	$\frac{1}{4}$	$\frac{49{,}65\,x^{1/2} - x^{7/6}}{64}$	$\frac{x^3}{56} \times \overline{\frac{49{,}65\,x^{1/2} - x^{7/6}}{64}}$
Heckboats or Pinks	$\frac{z x^{1+1/24}}{1{,}5}$	$\frac{x^{139/120}}{45{,}54}$	$\frac{x^{21/40}}{1{,}651}$	$\frac{2}{7}$	$\frac{38{,}8\,x^{21/40} - x^{139/120}}{64}$	$\frac{x^3}{54} \times \overline{\frac{38{,}8\,x^{21/40} - x^{139/120}}{64}}$
Cats or Barks	$\frac{z x^{1+1/20}}{1{,}5}$	$\frac{x^{23/20}}{43{,}2}$	$\frac{x^{11/20}}{2{,}147}$	$\frac{1}{3}$	$\frac{30\,x^{11/20} - x^{23/20}}{64}$	$\frac{x^3}{52} \times \overline{\frac{30\,x^{11/20} - x^{23/20}}{64}}$
Flat-bottomed Vessels, or Vessels with a small draught of water	$\frac{z x^{1+1/30}}{1{,}4}$	$\frac{x}{26}$	$\frac{x^{1/2}}{1{,}341}$	$\frac{1}{5}$	$\frac{24{,}23\,x^{1/2} - x}{32{,}5}$	$\frac{x^3}{63} \times \overline{\frac{24{,}23\,x^{1/2} - x}{32{,}5}}$

The preceding table N°. 1, according to which we may regulate all the proportions of merchant ships from the largest, as those engaged in the India trade, to the smallest, is founded on experience, and may serve as a guide in preparing the draught of a ship of any required tonnage.

But as it is not possible to form a ship, which combines in a certain degree all the qualities which may be wished, for this reason we have given in the table four species of ships.

In the construction of the first kind, under the denomination of *frigates*, it is to be considered, that they are to navigate in seas where hostilities are to be apprehended; which renders it necessary that they should carry a certain quantity of artillery, and at the same time sail well; and since the service of artillery requires a certain number of men, we may give to the ship a greater quantity of sail. With cannon, a ship has great weight above the water; besides it has to carry a greater quantity of sail; to have sufficient stability, it ought therefore to have its metacenter of a proper height above the load water-line. On which account it should have great length and breadth in proportion to the capacity of the hull.

The third kind, under the denomination of *barks* or *cats*, have few or no guns; they are built solely for trade; and their object is to carry the greatest possible lading, and sail with the smallest possible number of men. It is necessary that they possess, as far as it is practicable, the qualities which have been the subject of the above Articles.

The second species, under the denominations of *heckboats or pinks*, is that of vessels, which in regard to qualities, preserve a mean between the first and the third.

The fourth species, under the denomination of *flat-bottomed vessels*, have the same qualities with the third; but not having so great a draught of water when laden they want less ballast.

It will be more plainly seen by the tables and plans contained in my book of plates, what difference there is between these three species of ships.

Logarithms

$$P = 18200 = 4{,}2600714$$
$$P^{22/21} = D = 4{,}4676938 = 29350$$
$$52 = 1{,}7160033$$
$$3)\ 6{,}1836971$$
$$x = 2{,}0612323 = 115{,}14$$
$$4$$
$$5)\ 8{,}2449292$$
$$x^{4/5} = 1{,}6489858$$
$$1{,}476 = 0{,}1690864$$
$$z = 1{,}4798994 = 30{,}19$$
$$x = 2{,}0612323$$
$$0{,}0687077$$
$$x^{1-1/30} = 1{,}9925246$$
$$7{,}032 = 0{,}8470789$$
$$h = 1{,}1454457 = 13{,}978$$
$$x = 2{,}0612323$$
$$0{,}1030616$$
$$x^{1+1/20} = 2{,}1642939$$
$$1{,}76 = 0{,}2455127$$
$$D = 4{,}4676938$$
$$4{,}7132065$$
$$x^{1+1/20} = 2{,}1642939$$
$$\oplus = 2{,}5489126 = 353{,}9$$
$$x = 2{,}0612323$$
$$x^{1/2} = 1{,}0306161$$
$$8{,}4 = 0{,}9242793$$
$$k = 0{,}1063368 = 1{,}277$$

Logarithms

$$x = 2{,}0612323$$
$$3)\ 4{,}1224646$$
$$x^{2/3} = 1{,}3741548$$
$$18{,}8 = 1{,}2741578$$
$$d = 0{,}0999960 = 1{,}259$$
$$x^{1+1/20} = 2{,}1642939$$
$$z = 1{,}4798994$$
$$3{,}6441933$$
$$1{,}5 = 0{,}1760913$$
$$W = 3{,}4681020 = 2938$$
$$x^{23/20} = 2{,}3704171$$
$$43{,}2 = 1{,}6354837$$
$$V = 0{,}7349334 = 5{,}43$$
$$x^{11/20} = 1{,}1336777$$
$$2{,}147 = 0{,}3318320$$
$$S = 0{,}8018457 = 6{,}337$$
$$x^{11/20} = 1{,}1336777$$
$$30 = 1{,}4771213$$
$$30 \cdot x^{11/20} = 2{,}6107990 = 408{,}1$$
$$x^{23/20} = 2{,}3704171 = 234{,}6$$
$$2{,}2392995 = 173{,}5$$
$$64 = 1{,}8061800$$
$$L = 0{,}4331195 = 2{,}711$$
$$x^3 = 6{,}1836969$$
$$6{,}6168164$$
$$52 = 1{,}7160033$$
$$M = 4{,}9008131 = 79590$$

If we find it necessary to carry a certain quality to a greater degree than the proportions of the tables give, this alteration may be effected according to the principles laid down; but it must not be forgotten that we cannot improve one quality but at the expence of another. The table is so plain, that for its complete application, it only requires an example. Thus let there be required the proportions and dimensions of a bark of 200 lasts.
By a last is meant 18 skiponds iron weight; the skipond iron weight = 320 pounds; so that a last = 5760 pounds. A cubic foot of sea-water weighs 63 pounds; hence a last is nearly equal to 91 cubic feet of sea-water; so that 200 lasts = 18200 cubic feet of sea-water.
Thus it appears that a bark of 200 lasts ought to have 29350 cubic feet of displacement to the outside of the timbers; 115,14 feet in length from the stem to the stern-post; 30,19 feet of breadth to the outside of the timbers; 13,98 feet measured at the frame ⊕, from the load water-line to the upper edge of the rabbet of the keel; the surface of the frame ⊕ will be 353,9 square feet, the keel will have in depth from the upper edge of the rabbet 1,277 feet; there will be 1,259 difference of draught of water forward and aft; the surface of the load water-line will be 2938 square feet. The center of gravity of the displacement will be below the load water-line 5,43 feet; $\int \frac{\frac{2}{3} y^3 d\dot{x}}{D}$ or the distance of this center of gravity from the metacenter will be 6,337 feet; there will be between the metacenter and the common center of gravity of the ship and the lading, a distance of 2,711 feet; whence the moment of stability = 79590.

Fig. 32

To find immediately the properties of ships, proportioned according to table N°. 1, Figure 32 is constructed, where the numbers 20, 40, 60, &c. represent the length from the stem to the stern-post.
If *AB* be the load water-line for a bark, *CCB* is the locus of the center of gravity of displacement; *DDB* that of the metacenter; *EEB* that of the center of gravity of the ship and the lading. For a frigate, *FFB* is the locus of the center of gravity of the displacement; *GGB* that of the metacenter, *HHB* that of the ship with its lading. So that for a vessel of the form of a bark 80 feet long, the distance from the load water-line to the center of gravity of displacement = *LC*; the height of the metacenter above the load water-line = *LD*, this load water-line is above the center of gravity of the vessel with its lading by a quantity = *LE*.
But for a frigate, the distance of the center of gravity of the displacement below the water = *LF*, the height of the metacenter above the water = *LG*; the center of gravity of the ship and the lading is below the water by a quantity = *LH*. The line *IIB* determines the length the main-mast ought to have, so as to have the proper proportion according to the stability; that is to say, the length of the main-mast is as the distance of *IIB* from *AB*.
If there be given to large and small ships a form similar to that which is 110 feet in length, then the straight line *MB* will be the locus of the metacenter, and the other line *KKB* will determine the length of the main-mast, in the proportion required by the stability.
In determining the center of gravity of the ship and its lading, we have supposed the cargoes of ships to be similar; so that, if the bark of 80 feet in length has its center of gravity in *E*, the centers of gravity of other barks may be in the line *EEB*; in like manner, the centers of gravity of all frigates are in the line *HHB*.

Privateers are vessels, which an individual arms in time of war, by the authority of government, to take merchant ships and others belonging to the enemy.

In estimating the equipment of privateers, it must be considered, although some merchant ships are unable to make any resistance, that other large vessels may be encountered at sea, which are armed with guns. It is therefore necessary that privateers should be also well armed and have a sufficient crew, as well for action as for taking possession of their prizes.

For the attack of small ships the least privateers will do; but as these can only carry a few guns, the effect of which must be inconsiderable, their object should be to board; their principal force consists in the number of the crew.

If ships of superior force were not to be feared at sea, all sorts of ships might be employed in privateering, provided they were well armed with guns and men. But as a privateer may possibly meet with ships of the line, which are always of greater force, to escape in the chase, it should carry sail well, and sail fast in bad weather.

Independently of ships of the line, such a vessel is also liable to meet with frigates of war and privateers; with respect to privateers, as on each side they are armed by individuals, who have no other object but their own profit, it is not to be presumed that they will engage in a contest, from which nothing could result but mutual damage, without forwarding the views of their owners.

It is not so with frigates of war; their object is to attack and take, as much as possible, the enemy's privateers. If then a privateer cannot escape by its superiority of sailing (which since frigates are built to sail well is usually the case), it is necessary that it should be able to defend itself. The qualities of the vessel decide most frequently these combats. If the enemy be large and carry heavy guns, the privateer should also have them, and rather of a large caliber than in great number; which is more advantageous, not only on account of their greater effect, but also because there is a greater interval between the guns, so that the men at the oars and guns are not too much in the way of each other. These oars serve during the battle to present the privateer in an advantageous position, and in a calm to retire from a superior enemy. The privateer should sail well in all sorts of weather, and especially come about well; particularly, it should have a strong force in musketry, some small guns or swivels to fire case shot, and a good netting.

With respect to small privateers, as they are constantly forced to run from ships of war, their principal quality should consist in sailing well.

Besides the necessary qualities for action, the privateer ought to have a sufficient hold to carry stores, both of provisions and ammunition, for a cruise of a determined length, without sinking the vessel beyond a certain fixed depth.

Upon the whole it appears that the most advantageous qualities for a privateer are to sail fast, and to be sufficiently stiff to carry sail in bad weather.

We have seen in the previous chapter that to attain this object, it is necessary to give great length and breadth in proportion to the solidity of the immersed part. But as the construction of a ship of great length and of great breadth is very expensive, and requires a numerous crew to work it, it is not possible to carry these dimensions so far as might be wished; but one must be content with less than the greatest perfection in the property of sailing well, since the cost of the ship, with the pay and subsistence of the men, which amount to a great sum, would exceed the advantages gained. And as in constructing a privateer, certain views are entertained, which are to be carried into effect by a certain quantity of artillery, it is therefore the artillery, upon which the proportions ought to be founded.

The displacement of a ship, of which the size is known, as well as the weights it is to carry, may be found without difficulty; but it is not possible by theory alone, without the assistance of practical knowledge, to determine the true value, which the moment of stability ought to have.

By the comparison of different species of ships, it has been found, that privateers in general, large as well as small, have the proper stability, when the distance of their metacenter from the center of gravity of the ship is 6 feet; and since it is found that this center of gravity should be in the load water-line, the metacenter should be 6 feet above the load water-line.

The length, breadth, depth, and displacement, ought therefore to be so proportioned with respect to the guns and their position, that the center of gravity of the ship may be in the load water-line, and the metacenter 6 feet above.

But since these proportions, &c. cannot be found but by the means of approximation, to facilitate the investigation, I shall give hereafter general formulæ, which according to the weight, nature, and situation of the artillery, express the proportions of all kinds of privateers, from the largest frigate to the smallest sloop. For large vessels I have considered particularly the force of the artillery; with respect to the least, I have paid less attention to the artillery, than to the number of the crew, in which its whole force consists.

All vessels constructed from these proportions will be good sailers; and the smallest will sail equally well with the largest.

As the weight of the artillery and stores, which enter into the calculation and use of these formulæ, is the principal foundation thereof, I have thought proper to give the following table.

Weight of Guns and Stores proper for Privateers

Pounders	Weight of a shot in provision weight	Numbers by which the weight of the shot is multiplied to find that of the gun	Weight of the gun		Numbers by which the weight of the gun is divided to find the weight of the carriage, &c.	Weight of the carriages, breechings and tackles	Weight of the shot, powder, wadding equal the weight of 126 shot	Weight of the guns, carriages, breechings, tackles, shot, powder, and wadding		Weight of the guns, carriages, breechings, and tackles	
			Provision weight	Iron weight					A		C
Caliber	pounds		pounds	Skip		pounds	pounds	pounds	Cubic ft. of water 63 lb. each foot	pounds	Cubic ft. of water 63 lb. each foot
24	29	215	6235	19,48	4,70	1326	3654	11215	178	7561	120
22	—	216	—	—	4,63	—	—	—	—	—	—
20	—	218	—	—	4,56	—	—	—	—	—	—
18	21,75	221	4807	15	4,49	1070	2740	8617	136,77	5877	93,3
16	—	225	—	—	4,42	—	—	—	—	—	—
14	—	230	—	—	4,35	—	—	—	—	—	—
12	14,5	236	3422	10,69	4,28	799	1827	6048	96	4221	67
10	—	243	—	—	4,21	—	—	—	—	—	—
8	9 2/3	251	2426	7,58	4,14	586	1218	4230	67,1	3012	47,8
6	7,25	260	1885	5,89	4,07	463	914	3262	51,77	2348	37,3
4	4,833	270	1305	4,07	4,00	326	609	2240	35,55	1631	25,9
3	3,625	276	1000	3,12	3,93	254	457	1711	27,16	1254	20,0
Swiv. 3	3,625	70	254	0,80	—	60	400	714	11,33	314	5,0
Swiv. 2	2,416	70	169	0,53	—	42	266	477	7,57	211	3,35

In the above table, the weight of the gun is proportioned to the weight of the shot; and in order to follow uniformly the law of the increasing proportion between the shot and the guns, as the latter become smaller, we have been induced to put in this table several sorts of guns, which are not in use.

To proportion the weight of the gun by that of the shot, is not certainly the best method; it should be determined by other circumstances; however for the object in view, we may allow this method of proceeding, especially since it gives a result very nearly approaching to the ordinary weight.

There is moreover in the table, in columns A and C, the weight of the guns, which must be multiplied by the number to be carried by the privateer, of which the plan is required. In the calculation, the whole weight of the guns is made equal to A or C.

It may be allowed that a 24 lb. shot weights 29 pounds provision weight, a cubic foot of iron of this kind weighing 440 pounds; the same proportion is observed for the other shot.

In the following calculations, it is estimated that the weight of a man is 170 pounds = 2,7 cubic feet of sea-water, supposing one foot to weigh 63 pounds; the weight of a man and his effects = 4 cubic feet; the casks, provisions, wood for cooking during a month = 189 pounds = 3 cubic feet, of sea-water; the water including the cask, for 15 days = 112 pounds = 1,78 cubic feet.

$D =$ the displacement of the vessel to the outside of the timbers, $B =$ the weight of the part above the water comprising the masts, yards, sails, rigging; $a =$ the distance of the common center of gravity of these weights from the load water-line; $c =$ the distance of the center of gravity of all the guns, also from load water-line. The center of gravity of the lower tier of guns is supposed to be one-third the height of the middle port from its lower sill. In like manner, the center of gravity of the guns on the quarter-deck and forecastle is taken one-third of the height of the foremost port on the quarter-deck. For the center of gravity of the swivels, we take that of the middle swivel, $z =$ the breadth of the ship to the outside of the timbers, $y =$ the half breadth, and $x =$ the length from the forepart of the stem to the aft part of the stern-post; $d =$ the depth of the ship taken at the frame $\oplus$, from the load water-line to the rabbet of the keel.

We may also estimate the number of the crew to be $= 3{,}763\ A^{5/9}$, of which the weight is $= 10{,}16\ A^{5/9}$, and with their effects $= 15\ A^{5/9}$. The provisions for k months, and water for half the time, casks, wood, &c. included $= 18 \times kA^{5/9}$.

To be able to observe a certain order between these ships, we have supposed the largest provisioned for a longer time than the small ones, consequently, we may make $k = \dfrac{A^{2/7}}{2{,}756}$, whence $18 \times k \times A^{5/9} = 6{,}534 \times A^{53/63}$. If all the weights $15\ A^{5/9} + 6{,}534\ A^{53/63} + A = K$, the displacement will be well proportioned, D being $= 6{,}84 \times c^{1/4} \times K^{13/15}$.

Then we may make the weight $B = \dfrac{D^{21/20}}{6{,}281}$, and the distance $a = \dfrac{D^{1/3}}{3{,}48}$.

Make $C + 10{,}16 \times A^{5/9} = Q$, and let the center of gravity of displacement be below the load water-line by an unknown quantity m; the moment of stability will be expressed by $\frac{2}{3}\int y^3\dot{x} - (m+a) \times B - (m+c) \times Q$; but since $\frac{2}{3}\int y^3\dot{x} = (m+6) \times D$, then accordingly $(m+6) \times D - (m+a) \times B - (m+c) \times Q = 6\ D$; hence $m = \dfrac{aB + cQ}{D - (B+Q)}$.

It is necessary to take care in making a plan, that the center of gravity of the part immersed does not descend lower than this quantity; it would be better that it should be higher; for by making it lower, the stability will be diminished; the contrary will take place, if it be raised.

We have also found that $(m+6) \times D$, or $\frac{2}{3}\int y^3\dot{x}$ may be $= \dfrac{z^3 x^{21/20}}{26}$, and $z = \dfrac{x^{9/10}}{2{,}36}$; hence $(m+6) \times D = \dfrac{x^{15/4}}{341{,}8}$, and thus $x = \left(341{,}8 \times (m+6) \times D\right)^{4/15}$. The area of the load water-line should be $= \dfrac{zx^{24/23}}{1{,}626}$, and the area of the frame $\oplus = \dfrac{2{,}366 \times D}{x^{13/12}}$; also $d = \dfrac{x}{10{,}5}$. The center of gravity of the ballast is supposed to be below the plane of the load water-line by a quantity $= \dfrac{x^{7/5}}{95}$, and the weight of the ballast $=$

$$95 \times \left\{ \frac{1{,}11 \times \left((m+a) \times B + (m+c) \times Q\right) - mD}{x^{7/5} - 95\ m} \right\}.$$

We have found that the moment of the sails, in respect to the center of gravity of the ship or to the load water-line, should be $= \dfrac{35{,}56 \times 6\,D}{x^{1/3}}$.

As to the length x, which we have found here, it might be varied according to the distance between the guns, the disposition of the rowports, and the accommodations; this length, however, must not be much altered, if it be wished that the value of $\frac{2}{3}\int y^3\dot{x}$ should remain constant.

For a better guide, the following is the least distance, which can be allowed between the guns from center to center; for 24 pounders 10 1/3 feet; 8 pounders 8 5/6 feet; 4 pounders 7 11/12 feet; 18 pounders 9 5/6 feet; 6 pounders 8 1/3 feet; 3 pounders 7 1/2 feet; 12 pounders 9 1/3 feet.

But if it be wished to make two row-ports between each gun, the distance from gun-port to gun-port cannot be less than 8 feet.

The first port forward may be placed, so that the after side may be abreast of the center of the foremast; or that the foreside may be a little abast the after side of the foremast.

It is necessary to set off the distance between the after-port and the stern-post, one distance between the ports and one breadth of a port, more or less, according to the disposition of the accommodations.
It is proper in this place to insert the proportions of the ports, which experience has proved to be the best.

Pounders	Height of the Sills above the Decks	Height of the Ports	Breadth of the Ports
	Inches	Inches	Inches
24 pounds	28	34	40
18 ,,	26	31	36
12 ,,	24	28	33
8 ,,	22	25	30
6 ,,	20	22	27
4 ,,	18	19	24
3 ,,	16	17	21

For greater clearness, I give below the expressions in the order in which they should be employed in the calculations.

Formulæ for the proportions of Privateers.

$$15\,A^{5/9} + 6{,}534\,A^{53/63} + A = K$$

$$6{,}84 \times c^{1/4} \times K^{13/15} = D$$

$$\frac{D^{21/20}}{6{,}281} = B, \quad \frac{D^{1/3}}{3{,}48} = a, \quad 10{,}16\,A^{5/9} + C = Q$$

$$\frac{aB + cQ}{D - (B + Q)} = m$$

$$\text{weight of ballast} = 95 \times \frac{\left(1{,}11 \times (\overline{m + a} \times B + \overline{m + c} \times Q) - mD\right)}{x^{7/5} - 95\,m}$$

$$341{,}8 \times (m + 6) \times D^{4/15} = x$$

$$\frac{x^{9/10}}{2{,}36} = z, \quad \frac{zx^{24/23}}{1{,}626} = \text{area of the load water-line.}$$

$$\frac{2{,}366 \times D}{x^{13/12}} = \text{area of section } \oplus, \quad \frac{x}{10{,}5} = d$$

$$3{,}763 \times A^{5/9} = \text{the number of the crew}, \quad \frac{A^{2/7}}{2{,}756} = k \text{ months provisions.}$$

The distance which the center of gravity of the ballast is below the load water-line $= \frac{x^{7/5}}{95}$. The difference of the draught of water fore and aft $= \frac{x^{5/8}}{14{,}46}$.

The moment of the sails from the load water-line $= \frac{35{,}56 \times 6D}{x^{1/3}}$.

To facilitate the use of the formula according to the number of guns, their caliber, and the height of the battery, the following table has been constructed of the values of A, C, &c. for 16 privateers carrying different numbers of guns.

Number of the Ship	Guns				Height of the battery	Height of the ports	A third of the height of the ports	Dist. of center of gravity of guns of 1st battery from load water-line	Distance between the batteries	Weight of the first battery with carriages, breechings and tackles, &c.	Weight of the upper battery with carriages, &c.	Quantity C	Common center of gravity of all the guns above load water-line, or c	Quantity A
	First Battery		Second Battery, or that of quarter deck, and forecastle											
	No.	Caliber	No.	Caliber	Feet	Feet	Feet	Feet	Feet	Cubic ft.	Cubic ft.	Cubic ft.	Feet	Cubic ft.
1	28	18	12	6	8,5	2,58	0,86	9,36	6,4	2612,4	447,6	3060	10,29	4451
2	26	18	10	6	7	2,58	0,86	7,86	6,3	2425,8	373	2799	8,69	4074
3	26	12	10	4	6,5	2,33	0,77	7,28	6,2	1742	259	2001	8,08	2851
4	24	12	8	4	6	2,33	0,77	6,78	6,1	1608	207,2	1815	7,47	2588
5	24	8	8	3	5,75	2,08	0,69	6,44	6,0	1147,2	160	1307	6,85	1827
6	22	8			5,5	2,08	0,69	6,19		1051,6		1052	6,19	1476
7	22	6			5,25	1,83	0,61	5,86		820,6		821	5,86	1139
8	20	6			5	1,83	0,61	5,61		746,0		746	5,61	1035
9	18	6			4,75	1,83	0,61	5,36		671,4		671	5,36	932
10	16	6			4,5	1,83	0,61	5,11		596,8		597	5,11	828
11	14	6			4,25	1,83	0,61	4,86		522,2		522	4,86	725
12	12	6			4	1,83	0,61	4,61		447,6		448	4,61	621
13	10	6			3,75	1,83	0,61	4,36		373,0		373	4,36	518
14	8	6	Swiv.		3,5	1,83	0,61	4,11		298,4		298	4,11	414
15	1	12	16	3	4			4,5		147,0		147	4,50	277
16	1	18	16	2	3,75			4,0		101,4		101,4	4,00	188

Suppose it is required to make a plan for a privateer of 24 twelve pounders on the main deck, 8 four pounders on the quarter deck and fore-castle, with six feet battery, or the lowest sill of the middle gun port 6 feet above the water; this is the privateer number 4 of the table, so that there will be for A, C and c the following values.

By this process it will be found, that the privateer of 24 twelve pounders on the main deck, of 8 four pounders on the quarter deck and forecastle, and having the sill of the middle port of the lowest battery 6 feet above the water, should have 29140 cubic feet of displacement outside the timbers, not including the keel, the stem, and the stern-post.

The center of gravity of the said displacement will be below the plane of the load water-line 4,595 feet

$$\frac{2}{3}\int y^3 \dot{x} = 311600$$

The length from the stem to the stern-post 138,24

The breadth to the outside of the timbers 35,78

Ballast in cubic feet of sea-water 2616

Area of the load water-line .... 3769 square feet

Depth of the frame ⊕ from load water-line to rabbet of keel .... 13,16 feet

Area of frame ⊕ .... 330,7 square feet

Number of crew .... 296 men

Months for which provisioned 3,46

Quantity by which the center of gravity of the ballast should be below load water-line ... 10,45 feet

Difference of the draught of water .... 1,51 feet

Moment of sails from the center of gravity of the ship, or from the load water-line.......... 1202400

$A = 2588,\ C = 1815,\ c = 7{,}47$; log. 7,47 = 0,8733206; log. $c^{1/4}$ = 02183301

Logarithms

$A = 2588$ log.	= 3,4129643
$A^{5/9}$	= 1,8960913
15	= 1,1760913 N. N^r.
$15\,A^{5/9}$	= 3,0721826 = 1180,8
$A^{53/63}$	= 2,8712239
6,534	= 0,8151791 A = 2588
	3,6864030 = 4858
K	= 3,9358598 8627
$K^{13/15}$	= 3,4110785
$c^{1/4}$	= 0,2183301
6,84	= 0,8350561
D	= 4,4644647 = 29140
$D^{20/21}$	= 4,6876879
6,281	= 0,7980288
B	= 3,8896591 = 7756
$D^{1/3}$	= 1,4881549
3,48	= 0,5415792
a	= 0,9465757 = 8,842
B	= 3,8896591
a B	= 4,8362348 = 68590
$A^{5/9}$	= 1,8960913
10,16	= 1,0068937 C = 1815
$10{,}16\,A^{5/9}$	= 2,9029850 = 799,8
Q	= 3,4174717 = 2615
c	= 0,8733206
cQ	= 4,2907923 = 19534
aB + cQ	= 4,9450750 = 88124
D − (B + Q)	= 4,2734411 = 18769
m	= 0,6716339 = 4,695
$m + a$	= 1,1315224 = 13,537
B	= 3,8896591
$(m + a)$ B	= 5,0211815 = 105000
$m + c$	= 1,0851121 = 12,165
Q	= 3,4174717
$(m + c)\,Q$	= 4,5025838 = 31810
	5,1361178 = 136810
1,11	= 0,0453230
	5,1814408 = 151860
D	= 4,4644647
m	= 0,6716339
mD	= 5,1360986 = 136800
	4,1778250 = 15060
95	= 1,9777236
	6,1555486

Logarithms

$x^{7/5}$	= 2,9969025 = 992,9
95	= 1,9777236
m	= 0,6716339
95 m	= 2,6493575 = 446
	2,7379079 = 546,9
Ballast	= 3,4176407 = 2616
D	= 4,4644647
$m + 6$	= 1,0291808 = 10,695
$\int \frac{2}{3} y^3 \dot{x}$	= 5,4936455 = 311600
341,8	= 2,5337721
	8,0274176
x	= 2,1406447 = 138,24
$x^{9/10}$	= 1,9265803
2,36	= 0,3729120
z	= 1,5536683 = 35,78
$x^{24/23}$	= 2,2337162
	3,7873845
1,626	= 0,2111205
Area of load water-line	= 3,5762640 = 3769
d	= $\frac{138{,}24}{10{,}5}$ = 13,16
D	= 4,4644647
2,366	= 0,3740147
	4,8384794
$x^{13/12}$	= 2,3190317
Area of ⊕	= 2,5194477 = 330,7
$A^{5/9}$	= 1,8960913
3,763	= 0,5755342
Crew	= 2,4716255 = 296
$A^{2/7}$	= 0,9751326
2,756	= 0,4402792
(k)	= 0,5348534 = 3,426
$x^{7/5}$	= 2,9969025
95	= 1,9777236
Ballast below water	= 1,0191789 = 10,45
$x^{5/8}$	= 1,3379029
14,46	= 1,1601683
Diff. of draught of water	= 0,1777346 = 1,506
6 D	= 5,2426408 = 174840
35,56	= 1,5509618
	6,7936026
$x^{1/3}$	= 0,7135482
Moment of the sails	= 6,0800544 = 1202400

If the artillery had been planned otherwise, or if it were necessary to place the battery lower or higher, the proportions of the frigate would not be the same: however, it may be observed, that this height of the battery does not differ far from what is in common use.
To shew more sensibly the difference of form between small and great ships, which are constructed according to the proportions given according to the formulæ, Figure 34 is constructed, which is to be understood in the following manner:

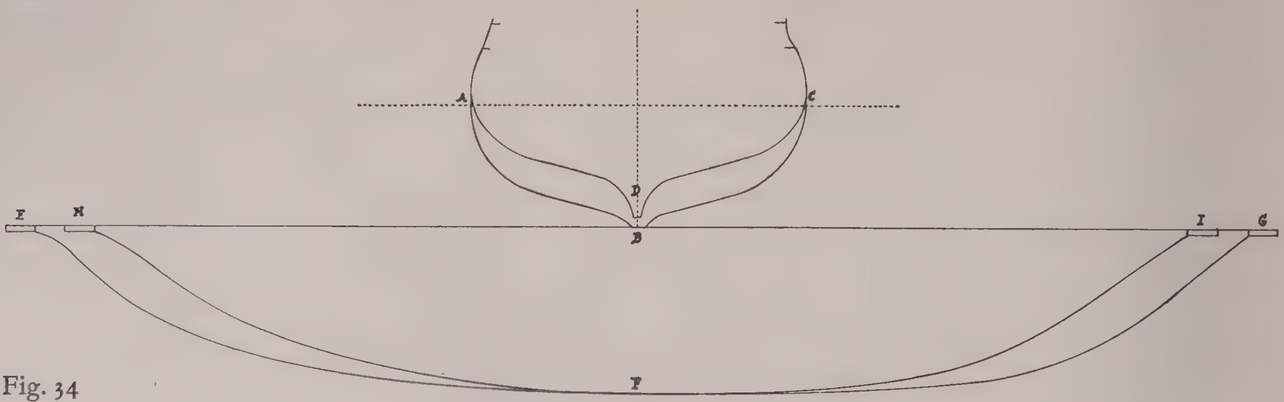


Fig. 34

ABC is the midship bend of a privateer 138 1/4 feet in length, and 35 3/4 in breadth; *ADC* is the frame $\oplus$ of a small privateer or boat 44 3/4 feet in length, and 13 feet in breadth, and *AC* is the load water-line; and according to the proportion, which there should be between the length and breadth, *EFG* will be the load water-line of the large privateer, and *HFI* that of the small one. These elements being known, it will not be difficult, with some knowledge of construction, and a little practice, to draw plans, which, every thing being well attended to, will differ little from those given in my *Architectura Navalis*, since the formulæ have been calculated after those plans; or to speak more correctly, they have been employed conjointly with others, in finding these different expressions.
I do not pretend to say, however, that one ought always to observe these proportions. Different cases present themselves, which may require different alterations: for instance, to navigate in seas where the waves are short and high, ships, particularly small ones, should have more breadth in proportion to the length.
In like manner, different kinds of rigging require alterations in the proportions: if the vessel be schooner rigged, it is necessary that it should have a greater relative length to allow a proper extent to the sails in proportion to the stability; the rigging of sloops on the contrary requires more breadth in proportion to the length.
There are privateers, which are obliged to go out to sea to meet with prizes; others have no occasion to go far from the coast; these two kinds ought to be provisioned differently; the one requires greater capacity than the other, although they may be of the same force, a circumstance which will necessarily cause differences in the principal dimensions; regarding it as an invariable principle, that the center of gravity of the ship with its lading, should be in the plane of the load water-line, and the metacenter 6 feet above.
As far as regards the accommodations, their distribution may be partly seen in the plans of my *Architectura Navalis*; but the size of the ships, and also the climates where they are meant to navigate, must influence greatly the nature of the accommodations.
Ships sufficiently large and stable should have large gangways, whereon to place the musketry, and they ought to be well netted on the gunwales.
In hot climates, ships should be more open, especially, if they are not liable to be sent on expeditions of long duration; but in cold climates, care should be taken that the crews be well sheltered: so that, in large privateer ships, instead of wide gangways, it would be more convenient to extend the quarter-deck and forecastle, with large gratings in the middle for the passage of the smoke in action. These gratings should be covered with tarpawlings in bad weather.
In some countries, they have their cables in the hold; in others, between decks; both methods have advantages and inconveniences. There are also different customs for the hours of meals, and for their galleys; some cook thrice a day; others cook only once: all this requires in a ship different arrangements, and what is right for one, is not convenient for the other.
Hence we see, how necessary it is to be acquainted with all these, and many other similar circumstances, before a draught is begun; and that it afterwards requires judgment and practice in the business, in order to arrange and adapt rightly, and according to circumstances, every particular thing; so as to include all possible conveniences, to have room to work the ship, and to avoid crowding.

The proportions then of masts and yards are founded on the length and breadth of ships in the following manner. As the breadth of ships has the greatest influence on the stability, the lower masts and top-masts should be proportioned to the breadth, whence not only the height of the sails, but moreover the height of their common center of gravity, will be in proportion to the said breadth; as to the breadth of the sails, or what is the same thing, the length of the yards, it should be proportioned to the length of the ship: thence it follows, that the moment of the sails will be as the square of the breadth, multiplied by the length. Small ships then will have a greater moment of canvass in proportion to the stability, than large ones; which agrees with what was observed above concerning the area of canvass for small ships: and it is a received custom for small ships, to increase the height of the lower masts still more, but at the same time to diminish that of the top-masts. The height of the main-mast of a trading ship with three masts, its breadth being $= B$, is $= 3{,}23\ B^{11/12}$, and the height of the main top-mast, reckoning from the upper side of the cross-trees, that of the main-mast being $= L$, is $\dfrac{L^{11/10}}{2{,}73}$ for frigates, and $\dfrac{L^{11/10}}{2{,}84}$ for barks. The relation of the masts, proportioned according to this method, to the masts proportioned according to the stability, may be seen by Fig. 32, where the line *BNN* determines the height of the masts in the proportion of $B^{11/12}$.

The length of the bowsprit outside of the stem, for frigates, is $1{,}15 \times$ the breadth of the ship, and for barks $1{,}1 \times$ the said breadth.

It is not sufficient to study merely to regulate the height of the masts, and the length of the yards, by the size of the ships; but also to use those which have such a proportion among themselves, that all the rigging may make a handsome appearance.

That the ships may be well rigged, it is necessary in the first place, that the fore-stay and main topmast-stay should be in a straight line, in like manner, the main-stay and the mizen topmast-stay: the fore-stay may end on the bowsprit, between one-third and two-fifths of its length from the small end; secondly, that the top-sails should be of similar figures, or at least, that their sides should be of the same cut; thirdly, that when the ship is seen, at one or the other of the extremities, the shrouds and the breast back-stays should appear parallel: this depends partly on the breadth of the channels, which ought to be regulated in a manner conducive to this end. To effect this, the length of the head of the main-mast, from the under side of the trestle-trees, which is 5/36 of the length of the said mast, being $= T$, the cap of the fore-mast should be lower than that of the main-mast by a quantity $= 2{,}22 \times T^{1/3}$ for frigates, and $= 2 \times T^{1/4}$ for barks. The cap of the mizen-mast should be on a level with the main-top.

If the length of the main top-mast $= S$, the length of the mizen top-mast will be $= 1{,}3 \times S^{6/7}$ for frigates, and $= 1{,}316 \times S^{6/7}$ for barks, supposing the length of the pole to be in the same proportion, as for the other top-masts; if it be longer, then that difference is added more.

The head of the mizen-mast ought to be 3/4, and that of the fore-mast 9/10 of that of the main-mast. The length of the fore top-mast should also be 9/10 of that the main; the head of these masts 1/9 or 2/17 of their length. The length of the top-gallant masts to the stop $= 0{,}54 \times$ the length of the top-mast; the length of the main yard $= 0{,}52 \times$ the length of the ship from the stem to the stern-post for frigates, and the main top-sail yard $= 0{,}79 \times$ by the length of the main yard; as for barks, the length from end to end being $= L$, the length of the main yard will be $= 0{,}6 \times L^{20/21}$; and the length of the main top-sail yard will be $= 0{,}81 \times$ by the length of the main yard. The main top-gallant yard $= 0{,}7 \times$ by the length of the main top-sail yard. All the yards of the fore mast are 9/10 of those the main-mast.

The proportion of the mizen top-sail yard to its mast, is equal to the proportion of the main top-sail yard to the main top-mast: the cross-jack yard $= 1{,}22 \times$ the length of the mizen top-sail yard for frigates, and $= 1{,}18 \times$ this length for barks. The sprit-sail yard = the fore top-sail yard; the sprit-sail top-sail yard = the fore-top-gallant yard.

The yard arms are 1/11 of their length for the lower yards, and those of the top-gallant yards; but 1/7 for the top-sail yards.

The distance of the center of gravity of the fore-mast from the perpendicular at the stem is 4/31 of the length. The center of the main-mast is 2/31 behind the middle of the ship. The distance of the center of the mizen-mast from the perpendicular at the stern-post is $= 0{,}182 \times$ by the length of the ship.

The main-mast should rake aft one foot in thirty; the mizen-mast should have double the rake of the main-mast; the fore-mast should be perpendicular; the elevation of the bowsprit, above the horizontal plane, should be in a length of 7 feet, about 4 feet for frigates, and 3 feet for barks.

It is according to these proportions that the masts and yards may be initially calculated; it will be however necessary, when the dimensions of the masts are given for the ship, to make a rigging draught, in order to proportion one according to the other, so that the whole may make a handsome appearance.

As to the diameter, experience has shewn that if the length of the main-mast, the main-yard and the main top-mast are denoted by L, R, and S feet, the diameter of the main-mast in inches will be $\frac{L \times R^{1/3}}{13}$; that of the main top-mast will be $\frac{S^{11/10}}{4,68}$; the diameter of the fore-mast will be 1/20 less than that of the main-mast; and the diameter of the fore top-mast will be 1/20 less than that of the main top-mast. The diameter of the top-gallant mast = 0,3 × their length reckoning to the stop.

The diameter of the bowsprit will be a mean between that of the main-mast and that of the fore-mast; the diameter of the jib-boom will be 3/4 of that of the main top-mast. The diameter of the mizen-mast 2/3 of that of the main-mast, and the diameter of the mizen top-mast 2/3 of that of the main top-mast.

The diameter of the main-yard, and that of the fore-yard in inches = 0,25 × the length of the yard; that of the top-sail yards = 0,23 × also by the length of the yards; that of the top-gallant yard = 1/6 of their length. The diameters of the sprit-sail yard, and cross-jack yard = 0,21 the length. The diameter of the sprit-sail top-sail yard = that of the main top-gallant yard. The diameter of the mizen peak is an inch for four feet in its length. The studding sail booms have two feet greater length than half the yard, and their diameter in inches is 1/5 or 1/6 of their length in feet.

The depth of the main-trestle-trees in inches is the fourth of the height of the top-mast in feet, less half an inch; the thickness of the fore-trestle trees is 1/16 less than that of the main-trestle-trees, and the mizen 3/5 of the main; the thickness of the top-mast cross-trees is 3/7 that of the trestle-trees of the respective tops. The breadth of the said trestle-trees and cross-trees is 5/7 or 3/4 of their depth.

The thickness of the caps is 4/5 of the diameters of the top-masts.

As the masts and yards taper towards their extremities, it is not sufficient to have their greatest diameters, it is necessary also to know the proportion according to which they are diminished, for the purpose of giving them the form which according to experience affords sufficient strength to sustain the efforts to which they are exposed. The distance between the greatest and least diameters is divided into four parts; the diameter at each of these divisions should be as follows.

The lower masts are found to be well proportioned when they have their diameter, at the height of the trestle-trees, one-eighth less than at the deck. So that, the diameter at the deck being 128, at the first division it will be 127, at the second 124, at the third 119, and at the fourth 112. The thickness within the trestle-trees will be 4/5, and above at the head, 5/8 of the diameter at the deck.

The top-masts have 1/5 less diameter under the cross-trees than at the cap of the lower masts. So that, the diameter at the cap being 80, at the first division it will be 79, at the second 76, at the third 71, and at the fourth, below the cross-trees 64. The thickness within the cross-trees and above at the head, will be 5/9 of the diameter at the cap.

If the great diameter of the lower and top-sail yards be 27, at the first division it will be 26, at the second 23, at the third 18, and at the outer end 11.

If the great diameter of the top-gallant yards is 32, at the first division it will be 31, at the second 28, at the third 23, and at the yard-arm 16.

The bowsprit has commonly at the outer end a diameter only one half of that at the gammoning; if the diameter at the gammoning is 60, at the first division it will be 59, at the second 55, at the third 46, and at the fourth 30.

Brigs and snows have their fore-masts and its appendages, as well as the bowsprit, of the same proportions as frigates. But the height of the main-mast of brigs ought to be such, that its top may be on a level with the cap of the fore-mast; the head of the main-mast is equal to the head of the fore-mast. The main top-mast is of the same length with the fore top-mast, the main yard and main top-mast yard are the same with the fore yard and fore-top mast yard.

In snows, the main-mast is a mean between the main-masts of a frigate and brig, so also the top-masts; but the main yard and the main top-sail yard, are of the same dimensions with those of frigates.

The length of the main-mast of schooners and galeasses to the hounds, ought to be thrice the breadth of the vessels; and in howker sloops the whole of the main-mast ought to be thrice their breadth.

The proportions for other masts and yards, as also for all of them, in small vessels, will be found in the draughts of Plate LXII. *Architectura Navalis*. The yards have there their half length.

East India ships have the length of the main-mast = 2,43 × their breadth; the length of the main top-mast = 0,586 × into that of the main-mast; the length of the main-yard = 0,54 × the length of the ship; the topsail-yard 0,8 × the main-yard; the main top-gallant yard 0,7 × by the top-sail yard; the mizen top-mast 3/4 of the fore top-mast.

The cap of the fore-mast is 2/5 of the length of the head of the main-mast lower than the cap of the main-mast; the cap of the mizen-mast is on a level with the main top. The other masts or yards are proportioned like those of merchant vessels frigate built.

In privateers the masts and yards are first proportioned, as for East India ships, after which a draught of them is made, in which are included the rigging and sails; lastly, their moment is compared with that of the stability, and the masts and yards will be determined, which are suitable to the moment of the sails.

On the construction of the scale of solidity

Suppose we wish to make the scale of solidity for the privateer (N°. 6, Plate XXXII), of which we have the displacement.

The calculation for the construction of this scale must commence from the plane of the load water-line, so as to obtain in succession the solidity between this and each of the lower water-lines; the operation is performed in the following manner.

To find the solidity of the part between the first and second water-lines.

Half the area of the load water-line	1293,91
Ditto of the second	1178,03
	2)2471,92
	1235,97
Multiplied by the distance between the water-lines	1,62
Half the solidity between the first and second water-lines	2002,27
Plank	50,73
Stem and stern-post	2,00
	2055,00 cubic feet
	2
Displacement of the part 1,62 feet below the load water-line	4110,00 = 45,16 lasts.

To find the solidity of the parts between the first and third water-lines.

Half the area of the load water-line	= 1293,91 × 1 =	1293,91
Ditto for the second	= 1178,03 × 4 =	4712,12
Ditto for the third	= 1030,69 × 1 =	1030,69
		7036,72
Multiplied by one-third the distance between the water-lines		0,54
Half the solidity between the first and third water-lines		3799,83
Plank		104,17
Stem and stern-post		4,00
		3908,00 cubic feet
		2
Displacement of the part 3,24 feet below the load water-line		7816,00 = 85,89 lasts.

To find the solidity of the pieces between the first and fourth water-lines.

Half the area of the third water-line	1030,69
Ditto of the fourth	856,93
	2)1887,62
	943,81
Multiplied by the distance between the water-lines	1,62
Half the solid between the third and fourth water-lines	1528,97
Half the solid between the first and third water-lines	3799,83
Half the solid between the first and fourth water-lines	5328,80
Plank	165,20
Stem and stern-post	6,00
	5500,00 cubic feet
	2
Displacement of the part 4,86 feet below the load water-line	11000,00 = 120,88 lasts

To find the solidity of the pieces between the first and fifth water-lines.

Half the area of the load water-line	= 1293,91 × 1 =	1293,91
Ditto of the second	= 1178,03 × 4 =	4712,12
Ditto of the third	= 1030,69 × 2 =	2061,38
Ditto of the fourth	= 854,93 × 4 =	4327,72
Ditto of the fifth	= 662,38 × 1 =	662,38
		12157,51
Multiplied by one-third the distance between the water-lines		0,54
Half the solidity between the first and fifth water-lines		6565,05
Plank		239,95
Stem and stern-post		9,00
		6814,00 cubic feet
		2
Displacement of the part 6,48 feet below the load water-line		13628,00 = 149,75 lasts.

To find the solidity of the pieces between the first and sixth water-lines.

Half the area of the fifth water-line	662,38
Ditto of the sixth	434,83
	2)1097,21
	548,60
Multiplied by the distance between the water-lines	1,62
	888,73
Half the solidity between the first and fifth water-lines	6565,05
Half the solidity between the first and sixth water-lines	7453,78
Plank	335,22
Stem and stern-post	12,00
	7801,00 cubic feet
	2
Displacement of the part 8,1 feet below the load water-line	15602,00 = 171,45 lasts

To find the solidity of the pieces between the first and seventh water-lines.

Half the solidity between the first and seventh water-line	7957
Plank	426
Stem and stern-post	16
	8399 cubic feet
	2
Displacement of the part 9,72 feet below the load water-line	16798 = 184,6 lasts.

To find the solidity from the load water-line to the keel.

Half the solidity between first water-line and the keel	8105	
Plank	500	
Stem and stern-post	20	
Displacement of the part 11,72 feet below the load water-line	8625	cubic feet
	2	
	17250	= 189,56 lasts.

To construct from hence a scale of burden.

Draw two lines perpendicular to each other, the one in a horizontal direction, the other in a vertical direction; make on the horizontal line a decimal scale at pleasure to represent lasts, and on the vertical another scale of feet also at pleasure, as is seen in Plate IV.

Below the horizontal line and at the distance from this superior line of 1.62, 3.24, 4.28, 6.48, 8.1, 9.72 and 11.2 feet, draw parallels thereto.

On the scale of lasts, take the quantities, which have been found, in lasts 45.16, 85.89, 120.88, 149.75, 171.45, 184.6 and 189.58; set off these quantities on the corresponding horizontal lines, from the vertical line.

Through all the points so determined pass a curve, and you will have a scale of solidity.

The horizontal scale is in French tons, English tons, and Swedish lasts.

The vertical scale, at right angles to the horizontal one and marked *S*, *E*, and *F*, is in Swedish, English and French feet. The curves marked No 1, No 2, No 3 etc., all of which meet at *e*, determine the burden of the vessels No. 1, 2, 3 etc. on Plates I, II, III, IV, V, VI and VII.

The method of using the scale is this.

The line *ab* on the sheer plan is the load water-line, the privateer being laden. Suppose that the water-line before it is entirely laden, were *cd*; then the distances *ac*, *bd* are taken, which by the scale of the plan give 4 feet 11/2 inches and 5 feet 11/2 inches; these two quantities are added, and half the sum is taken, 4 feet 71/2 inches.

Take this quantity 4 feet 71/2 inches on the scale of solidity, you will have *eg*, which must be transferred perpendicularly to the line *ef*, until it meet the curve in *h*. From *h* draw the line *hi* perpendicularly to *fe*, or what is the same thing, parallel to *eg*; this line marks on the scale of lading the weight, which must be put on board to bring down the ship to the line *ab*, namely, 175 Swedish lasts.

If the ship be quite light, one may in this manner find the lading, which it can take; or if the water-line of a ship has been once observed, supposing another to be found, one may be able, by means of the said scale, to obtain the weight which the ship has taken on board, or of which it has been discharged, to render it so much more brought down, or more raised.

If similar scales were made by builders for all ships and vessels constructed by them, the owner or commander would have it always in his power to determine the lading he could take on board, and that with such exactness as not to be deceived one last in the largest ship, when the load water-line was determined.

This scale is particularly necessary for ships of war or privateers, to the end that knowing the quantity of provisions and other stores, which they can take, the ballast may be determined, which they can receive without being brought down farther than the load water-line.

On the measurement for tonnage

By measurement for tonnage is meant the taking of the dimensions of a ship, in order, from the consideration of its form, to find the lading it can carry, and with which it can navigate without danger.

To measure for tonnage in the Swedish manner, is to determine the number of lasts, which the ship can carry, as follows.

The length of the ship is taken on the upper deck from the stem to the sternpost, the breadth within the ceiling, and the draught of water from the plank of the said upper deck to the plank of the bottom, these three dimensions are multiplied together, and the product is divided by 200; the five-sixths of the quotient will be the weight, which the ship can take in lasts of 18 skiponds iron weight *per* last; as much *per cent.* however is subtracted from this quantity as the measurer judges the ship more or less full in the floors, or as it carries a greater or less number of guns. The remainder is the burthen in lasts.

It follows from hence that if two ships were constructed from the same plan, but the upper deck of the one placed one foot higher than that of the other, the former would be found of a greater quantity of lasts than the latter; which ought however to be the contrary, for the former ship ought to carry less, as its sides being raised a foot weigh more (the two ships being laden to the same draught of water). The result of this calculation may moreover be erroneous on this account, that the degrees of the ship's rising, more or less, will not be always estimated correctly by a person in the hold; whence it happens that the addition or subtraction on this account must be in a great measure arbitrary; without mentioning other reasons, which render the measurement for tonnage, by this method, very uncertain.

If a last were a certain space, this manner of measuring would be more tolerable, but as it is a weight, it is altogether without reason.

The method of measuring for tonnage in England, is not used for the direct purpose of finding the quantity of lasts which the ship can carry, but to obtain the content, according to which the ship pays the duties.

The capacity is found thus: the product of the length of the keel multiplied by the breadth of the ship to the outside of the plank, and again by the half breadth; this product, I say, divided by 94, gives the capacity of the ship in tons. If the ship carries more than this quantity, it is said to carry more than its measurement for tonnage, and *vice versâ*.

Little need be said in regard to this method, because the immediate object of it is not to find the burthen; however the manner of determining the length of the keel, upon which length the calculation is founded, is faulty; 3/5 and 1/8 of the breadth of the ship are taken, for the rake of the stem and stern-post; these two quantities are subtracted from the length taken from the aft side of the wing transom at the middle line; the remainder is considered as the length of the keel. That this method is erroneous appears as follows.

Let the length of the ship from the stem to the stern-post equal m, and its breadth $= n$; then the length of the keel $= m - \left(\frac{3}{5} + \frac{1}{8}\right) \times n$. And as $\frac{3}{5} + \frac{1}{8}$ make nearly $\frac{3}{4}$, one may say that the measurement of the ship in tons, by the preceding rule, will be $= \frac{(m - 3/4\, n) \times 1/2\, n^2}{94}$. If this expression be made $= 0$, then the tonnage of the ship is equal to 0; it could therefore carry nothing. It is true, that to make this the case, the breadth of the ship must be 4/3 of the length, which is never the case.

Since when a ship is built by contract, it is usual to give so much *per* ton, it would follow from this method of measuring, that it is advantageous to the owner to give great breadth in proportion to length.

These two methods of admeasurement being entirely defective, I give here the view which ought to be taken of this operation, from which will be seen the method of measuring a ship exactly, in order to determine the weight it can carry.

It is known that the weight a ship can carry, is always equal to the displacement of water which that weight occasions; the question then is only to measure the part of the ship, which is to be immersed in the water by the weight of the cargo. This measurement may be made with greater or less exactness. I shall give here the process necessary to attain the object in view, which is the most simple, but at the same time the least exact.

The ship, when its admeasurement is taken, is supposed to be light; its draught of water is taken in this state forward and aft; afterwards the draught of water is determined forward and aft, which it is to have when the lading is in: hence the number of feet is known, to which each extremity must be brought down; these are added together, and half their sum taken. There are known; first, the quantity which the ship would be brought down by the effect of the lading; secondly, its length, which is measured from the wing transom; thirdly, its breadth which is taken to the outside of the plank: these three dimensions are multiplied together, and the product is divided, if the ship be full at its extremities, by 110; if on the contrary it be lean, by 115; and the quotient is the burthen of the ship in lasts. But if the vessel be a store-ship or have the form of one, keeping its greatest breadth almost the whole length, and also full at the extremities, 105 is taken for the divisor.

For example, a ship has length in a straight line before the wing transom 134 feet, and breadth to the outside of the plank 34 feet.

Suppose that it has a draught of water, when light, abaft 12 feet, forward 8 feet 7 inches; suppose also that the draught

of water, when laden is abaft 19 feet, and forward 18; subtracting twelve feet from 19, 7 will remain; and subtracting 8 feet 7 inches from 18 feet, 9 feet 5 inches will remain, which added to 7 feet, will make 16 feet 5 inches, half of which is 8 feet 21/2 inches, which the lading should bring the ship down. Multiplying 134 feet, 34 feet, and 8 feet 21/2 inches together, the product will be 37400.

If the ship be a bark, or supposing it to be full in its extremities, this number must be divided by 110, and the burthen of the ship will be 340 lasts; if it be a frigate, or a ship very sharp fore and aft, the divisor will be 115, and the ship will carry 3251/5 lasts; if this ship be fuller above and below, as well as at the extremities 112 might be used as the divisor, and it would carry 33313/14 lasts.

This method also depends partly on the correctness of the eye, in estimating the degree, more or less, of the rising of the ship, and choosing in consequence the divisor; it is to be attained by a little attention and practice. The measurer will not be deceived thus 5 lasts; and according to the common method of measuring, he may make an error of 40 lasts for ships of this size.

One might perform the operation with more exactness, by taking more breadths independently of the middle one, and then there ought not to be an error of one last; but as this would require more time, to take the measures and make the calculations, I shall not enter upon it.

In loading a ship, it is necessary to take care to put no more on board than the lading which is consistent with its sailing.

For example: If the ship has ballast in, when measured, it is necessary to add its weight to the burden, which has been found for the vessel: but if the water, the provisions, the guns and ammunition, &c. are not on board, if there be wanting only a cable, a sail, or any thing of this kind, their weight when known must be subtracted from the burden given by the measurer.

To estimate these things, it may be supposed that provisions with the casks and wood for one man, for one month, weighs 186 provision pounds. The water also for one man for the same time 217 pounds: the man himself with his effects 260 pounds.

When the number of the ship's crew is known, the time for which it is to be provisioned and watered, it is not difficult to find the total weight of these things.

The weight of a 12 pounder with its carriage, breeching and tackle, is very nearly 13 skiponds; that of an 8 pounder with the same, is 10 skiponds; of 6, 8 skiponds; of 4, 6 skiponds; of 3, 41/2 skiponds; of 2, 31/2 skiponds; all iron weight. The powder, shot, wads, &c. should be an eighth of the weight of the gun and its carriage, in time of war; in time of peace, less.

The galley and cooking utensils (if these be not on board) may be estimated at 30lbs. for each man of the crew.

It is necessary to see in like manner if it want cables, hawsers, or other parts of the rigging. The square of the circumference of the cordage divided by 4, gives the weight of a fathom of the said cordage.

Thus it is required to find the weight of a 15 inch cable; the square of 15 is 225; dividing 225 by 4, you will have 561/4lbs. for the weight of a fathom of this cable. A hundred fathoms of it will, therefore, weigh 2625lbs. which makes nearly 14 skiponds, provision weight, or 17 skiponds, 10 lisponds, iron weight.

If the rigging be wanting altogether, it may be supposed that the weight of the whole for a ship, frigate-built, with the masts, is equal to its burden in lasts, divided by 1,88; but for a bark, which has less rigging in proportion to the lading it can carry, the divisor will be 1,98. For ketches, galeasses, howker-sloops, the divisor should be 2,5; this is sufficiently exact for the object in view.

On the accommodations for provisions

When it is necessary to make accommodations for the provisions, as bread, peas, grain, &c., supposing the number of the crew, and the time for which the ship is to be provisioned, to be known, it is easy to determine the capacity which the store-rooms should have; and it is the more necessary to make an exact calculation in this respect, because there is always in ships very little space for things which are essential, particularly in ships of war. If too much be taken for one thing, there will be space wanting for another.

For example, if we wish to know the size it is necessary to give to the bread-room of a ship with a crew of 24 men, to be provisioned for six months:

The amount of bread for one month, weighs 21 1/2 pounds; that for six months 129 pounds, and consequently 3096 pounds for the whole crew for six months. The cubic foot of biscuit weighs 26 pounds; divide this number 3096 by 26, the quotient will be 119 cubic feet, which is the space which the biscuit should take up, being well stowed.

Thus may be found the room proper for putting the peas: one man being allowed 45 quarts *per* month, that is, 270 quarts for 6 months, and consequently 6480 quarts for the whole crew, for the same time, which makes 810 kans, or 14 1/2 tons; and as the ton contains 5,6 cubic feet, multiply this quantity 5,6 by 14 1/2, the product will be 81; wherefore there will be wanted for the peas a space of 81 cubic feet.

It is necessary, however, to give a little more space than the result of the calculation, which depends on the place where the passages into the store-rooms can be worked.

In a similar manner, if the ship take three months or 91 days' water, 1 1/3 kan to a man *per* day, which will make for one man for three months 121 1/3 kans, and consequently 2912 kans for the whole crew. The space which the proper casks will take up, is found by means of their dimensions.

Thus also by the dimensions of barrels of powder, the length and diameter of cartridges filled up, the size is found which must be given to the powder room and ammunition chest, and also their distribution.

Contents

Printed in the German Democratic Republic
Typography: Wolfgang Heincke
Jacket: Siegfried Berning
Production: C. G. Röder, Leipzig

This edition first published in 1971
by Adlard Coles Ltd 3 Upper James Street
Golden Square London W1
ISBN 0 229 97491 0